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The design of a solar collector and its implications for sustainable design methodology



December 2001

megan strickfaden

*A support document in partial fulfillment of the
Master of Design degree.*

Industrial Design
Department of Art and Design
University of Alberta
Edmonton, Alberta, Canada



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THE UNIVERSITY OF ALBERTA
FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty
of Graduate Studies and Research, for acceptance, a thesis entitled:

Final Visual Presentation

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*This thesis is dedicated to my
children Kai and Aerlan
and to my students for what
they teach me.*

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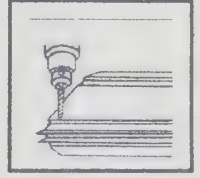
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Abstract



This paper explores industrial design within the context of sustainability applied to the redesign of a flat-plate solar collector. Based on the fact that environmental issues have become more prominent in present day society and the design world, affecting the design process and the role of the industrial designer, a holistic approach has been taken—one which involves material selection, production processes, technology, and people. The design is based on one originally designed by Professor Tang Lee of the University of Calgary. In collaboration with Professor Lee and SESCI-Northern Alberta Chapter, a manufactured kit for self-assembly has been designed. The kit includes a liquid heating flat-plate solar panel with an instructional leaflet and recommendations for product manufacture, product support, and product disposal/reintegration. The outcome is a flat-plate solar panel design that is durable, user-friendly, non-toxic, and created with carefully selected materials. Using a methodology that involves collaborative design, cradle-to-cradle design, and one that assesses ecological consequences, the redesign maintains and exceeds presently attainable technical advances.

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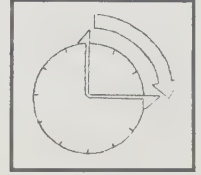
Symbols and Abbreviations



AC	alternating current
CN	Canadian National Railways
CNC	computer numerical control
CSA	Canadian Standards Association
DC	direct current
EPDM	copolymer of ethylene and propylene plus diene
EPSB	Edmonton Public School Board
HETH	Human Ecology Theme House

LEBDA	Low Energy Building Design Awards
MDF	Medium Density Fiberboard
NSTF	National Solar Testing Facility
OPEC	Organization of Petroleum Exporting Countries
OSB	Oriented Strand Board
PASEM	Program of Assistance to Solar Equipment Manufacturers
PC	polycarbonate
PE	polyethylene
pH	the hydrogen ion concentration in a liquid
PMMA	polymethyl methacrylate
PP	polypropylene
psi	pounds per square inch
PUR	polyurethane
PUSH	Purchase and Use of Solar Heating
PV	photovoltaic
PVC	polyvinyl chloride
R-value	resistance to heat flow
SESCI	Solar Energy Society of Canada Inc.
SESCI-NAC	Solar Energy Society of Canada Inc. – Northern Alberta Chapter
USGPM	United States gallons per minute
UV	ultraviolet

Context: industrial design and sustainability



Since its beginning, mainstream industrial design has traditionally concentrated on design as business within the narrow context of an Industrialized market economy. Design has been done primarily as design-for-profit, often including planned obsolescence. The general perception of design is that it has been ‘married’ to business and economics for the greater part of the past 150 years. Even the Canadian government department of Human Resources Development published a document stating that the future of design is central to economic development.¹

To fulfill design-for-profit, industrial design has been primarily an artistic form of expression—style, fashion, and trend—that sells more products. Industrial designers are taught to respect their clients’ freedoms: freedom to create, freedom to produce, and freedom to market any desired product. This concept prevails in North America since materialism and conventional consumerist habits are powerful. The Industrial Age focused on the mastery of materials and efficiency—a focus on material possessions creating a web of relationships between people and objects. As the world moves out of the Industrial Era and into the Information or Communications Era, the industrial designer and what industrial design represents is shifting.

Industrial design balances somewhere between engineering and fine art, and is a study of the product-user interface. Throughout modernism the designer focused primarily on the formal qualities of visual communications—the elements and principles of design. In the Information Era, designers must increasingly consider that which has become known as the intangibles of design (see Appendix 2). These are aspects of design that have always been present but not necessarily at a conscious level for all designers. The awareness of the intangibles of design and a focus on user groups are what distinguish the designer from the artist. That is not to say that intangibles are not part of the art-making process; however, it is the conscious embodiment of cultural context, philosophy, symbols, and value into an object

that makes designing a unique activity. Increasingly, the designer is asked to represent tangibly, in objects, the concepts of the intangible.

Sustainable design, the buzz phrase of design in the early 21st century, can be traced back to the mid-20th century and earlier. Sustainable design was ‘born’ during a period when theoreticians, philosophers, and designers were beginning to make a break from the concept of one-world technology and the tenets of modernism rooted in the Industrial era. It arose from the Western *doing* society; a perceived progress in the design and production of goods.² The ideology of Industrial progress has been efficiency, rationality, and control. Progress has been equated with the Darwinian theory of evolution and the acceleration of human activity in science, commerce, communication, transportation, entertainment, and leisure activities. Western societies’ sense of progress can be shown with this example: we flew like birds by 1903 and dropped bombs by 1914. Progress and design should be so much more than this.

“Sustainability is hard to sell as a grueling regime of limits—but not if we recast it as progress.”

Figure 2: John Thackara, 1999.

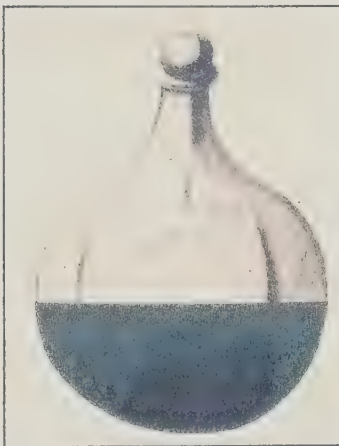


Figure 3: *We flew like birds*

Throughout the Industrial era, there have been individuals and groups who have objected to this idea of progress and the apparently unseen side of the coin: degeneration and decadence. Industrial designers such as Richard Buckminster Fuller and Victor Papanek began to scrutinize the ‘evils’ of a culture linked to the free-market system. These designers recognized a global imbalance and a culture that defined ‘free’ as big and powerful but not necessarily accountable. Furthermore, the Environmentalist movement, which began on the periphery of mainstream, recognized that Industrial economies had separated production

processes from the land, the land from people, and economic values from personal values. Sustainable design is linked to the values of Fuller and Papanek, and to Environmentalism where the concept of ‘deep ecology’ perceives no separation between planet Earth and the beings on it.

Environmental issues cannot be resolved by design; however, mainstream 21st century designers are beginning to assess how design decisions are impacting people and their surrounding environment. What was considered alternative in the 1920s and 1970s are now becoming more central with large numbers of designers and institutions exploring concepts that were considered out of the norm in the 20th century. For example, *eternally yours*⁴ in the Netherlands works towards promoting longevity and durability in product design. *Droog*⁴ design, also from the Netherlands, encourages the designer to re-use materials creatively in order to provide a forum for discussion amongst designers and consumers. *Inflate*⁵, a design group from the United Kingdom adds humour to people's everyday lives by creating unusual inflatable objects, such as clothing, salt shakers, and vases, and simultaneously use less materials for manufacture. Institutions such as the Delft University in the Netherlands, the Royal Melbourne Institute of Technology in Australia, and the Centre for Sustainable Design in the United Kingdom are all actively pursuing ideologies that relate to sustainability. Mainstream designers such as Frank Gehry, Kareem Rashid, and Philip Starck are designing products that embody specific concepts of sustainability. These principles, that demonstrate concern for the environment, are becoming more mainstream even though it is presented as fashion—such as Gehry's use of cardboard for furniture and Rashid's minimal use of materials. Increasingly, there is a shift from the designer focusing on the elements and principle of design, to a focus on the intangibles of design. Furthermore, designers are exploring the concept of immateriality⁶ in design, whereby objects are created with embedded meaning to create a stronger relationship between the designed product and the user/audience.⁷

Industrial design has been perceived by some as being one of the great causes of environmental ills. In the re-definition of the industrial design profession, the design process is no longer considered to resemble a mathematical configuration. It is understood that there are many variables in designing; therefore, design-by-formula is not possible. In sustainable design, it is recognized that no outcome is permanent—there is no one answer. In the Information era, design has evolved beyond the linear concept of materials, production, and advancing technology. Designers are

“There are professions more harmful than industrial design, but only a few of them.”

Figure 4: Victor Papanek, 1971.

beginning to analyze and address a broader spectrum of issues through different perspectives: systematically, ecologically, and holistically.

Furthermore, there is now a recognition that the role of the designer is no longer

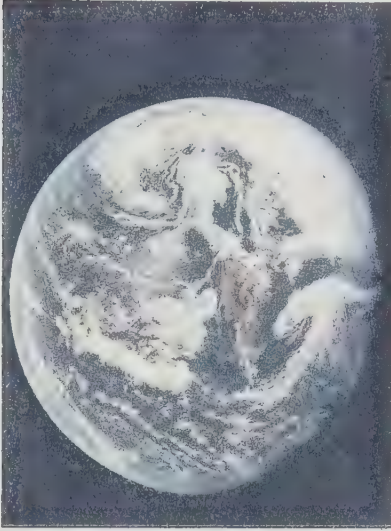


Figure 5: Earth

isolated but part of a community since s/he must act with this community in mind. The design process is evolving into a dynamic process where the designer engages with a number of groups and individuals in order to make design decisions reflecting a broader spectrum of needs. “User-centered design” and “interdisciplinary design” are design concepts that have been recently coined and these are part of the sustainable design philosophy.

Sustainable design reintroduces ideas of ethical and social responsibility, cultural and geographical locale, and the concepts of time and time-scale that were present long before Industrialization. Sustainable design began as a critical approach to mainstream design; however, now, a

wider interpretation of the design process has created a shift from strictly design reform to a quest for a better model for design. By breaking the ‘abundance-production-consumption’ chain, seen throughout the 20th century, the designer works towards a more intrinsically-complex system.

It is with the understanding of the above context that I became involved with the analysis and redesign of a flat-plate solar collector at the University of Alberta.

¹ Jones, Francine, ed. *Shaping Canada's Future by Design*. (Ottawa: Human Resources Development Canada, 1996) 9

² “Prometheus of the Everyday—The Ecology of the Artificial and the Designer's Responsibility”. *Design Issues*. (MIT Press, Vol. IX, No. 1. [Fall 1992]) 8-10; 16-18.

³ van Hinte, Ed, (ed.) *Eternally Yours—Visions on Product Endurance*. (Rotterdam: 010 Publishers, 1997).

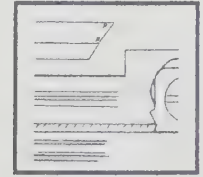
⁴ Ramakers, Renny and Gijs Bakker, eds. *Droog Design—Spirit of the Nineties*. (Rotterdam: 010 Publishers, 1998) and *Droog and Dutch Design*. (Utrecht: Centraal Museum, 2000).

⁵ *Inflate—Swell*. (Frankfurt: Verlag, 1998).

⁶ Moles, Abraham M. “Design and Immateriality—What of it in a Post Industrial Society”. *The Idea of Design*.

(Massachusetts: MIT Press, [1998]) and Baharam, S. “Product Symbolism of Gandhi and its Connection with Indian Mythology”. *The Idea of Design*. (Massachusetts: MIT Press, [1998]).

⁷ Walker, Stuart. “How the Other Half Lives: Product Design, Sustainability, and the Human Spirit”. *Design Issues*. (The MIT Press, Vol. 16, No. 1. [Spring 2000]).



Project background: influences towards redesigning a solar product

In the years between completing my undergraduate degree and the onset of my graduate studies at the University of Alberta, I began to question the practice of Industrial design being perceived as a 'style-based' profession. I frequently worked for non-profit organizations taking pleasure in knowing that I was balancing function, users' needs, and aesthetics with designing for a good cause. Furthermore, my attitude towards design was greatly influenced by a design project that I worked on for six months while living in Mexico in the State of Baja California. The project was in an impoverished area, a small village called



Figure 6: Pescadero, BCS, Mexico

Pescadero, with just under 200 villagers. I was hired to implement a solar panel for electricity production and to design an irrigation system for the 900-acre ranch that was more desert than fertile land. In these interim years between my studies, I became increasingly more interested in the effect of design including socio-cultural elements and environmental impact.

The first year of my graduate studies provided me the opportunity to explore a variety of effects from the practice of design. I was influenced by Dr. Shawran Kumar¹ who described ergonomics as a study of multi-factorial, multi-dimensional, interconnection of systems. This 'systems approach' to analyzing a design problem influenced my desire to find a more holistic approach to the design process. In preparation for choosing a thesis project, I sought information from areas that I perceived as counter movements in industrial design. I discovered EcoReDesign^{TM2} in Australia, green design³ in Britain and sustainability⁴ in North America. I began to recognize that the 'systems approach' described by Dr. Kumar was a thought process that could be easily applied to the design process. Background readings in design theory and history led me to form a set of basic principles relating to sustainable design that could be applied to product design (see Appendix 3). The development of these principles provided me

with a background with which to identify key issues in the areas of material selection, manufacturing processes, product use, and the practice of industrial design. In an attempt to expand the criteria for designing products, I recognized that the criteria should include: technology, materials/manufacturing, people, and the environment. A more complex set of criteria for designers, such as these, mirror the study of ecology in which the concepts of

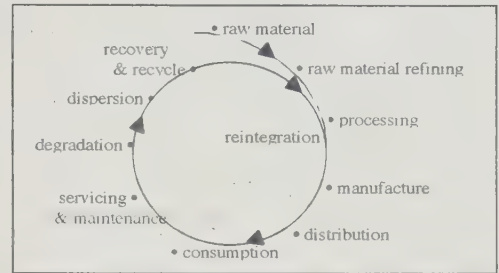


Figure 7: *Cradle-to-cradle approach to material design*

sustainability and regeneration are central. With a greater number of variables, human-based issues and environmental issues are balanced. In the studies of ecological design, life-cycle cost analysis (LCA)⁵, and the phrase 'cradle-to-grave' articulates concepts beyond the chain of production-consumption (see Appendix 4). These ideas have further evolved and are described in the phrase 'cradle-to-cradle'. In addition to background readings, I sought out individuals and groups on campus, and in the community who were involved with projects relating to sustainability.

In January 2000, I became involved with projects at the Human Ecology Theme House (HETH) directed by Dr. Sandra Niessen of the Human Ecology department at the University of Alberta. HETH is located at 11025 Saskatchewan Drive on the university campus in

Edmonton, Alberta. It is a three-bedroom residence, built in 1926, that will undergo renovations over the next several years. The renovation process recognizes the inherent qualities present in the existing structure and infrastructure of the house. Dr. Niessen encourages inter- and trans-disciplinary⁶ activities by collaborating with professionals and academics. In this way, university students and the community-at-large are exposed to issues of sustainability.

The first project I became involved with at HETH was as a team member in re-designing the kitchen. From my experiences at HETH, I came to realize that sustainable design



Figure 8: *Tang Lee discussing solar collectors at the Human Ecology Theme House*

should not be retrofitted to design, but that it should be an intimate and integral component of the design process from its inception.

It was my continued involvement with HETH that provided me with the opportunity to analyze and construct a solar panel. It was the summer break and I was assisting and participating in a workshop with architect and professor Tang Lee of the Faculty of Environmental Design at the University of Calgary to build two water-heating solar collectors for HETH. Simon Knight of Climate Change Central, a not-for-profit agency of the Alberta government, approached me and asked if I would be interested in re-designing the flat-plate solar collector



Figure 9: *Solar panel construction at HETH*

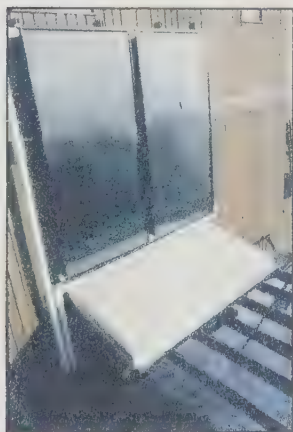


Figure 10: *Flat-plate solar collector at the Lee residence in Calgary*

with a focus on ease of manufacture and assembly.

Simon Knight stated that he was interested in being involved in the design process. His concern for the environment and involvement with Climate Change Central presented the unique opportunity to work with the provincial government. Professor Lee was supportive of the proposed project as he viewed it as an opportunity to further the study of sustainability and to support the perspective of an industrial designer.

The original solar collector design had been engineered for efficiency and was known to be effective as a thermal solar heating unit. The solar collector had undergone several generations of changes and had been used in architectural designs since the 1970s. However, the solar collector had never been analyzed or commercialized from an industrial design point of view.

As described above, from the onset, this project has been a collaborative effort involving the input, consultation, and support of a number of individuals and groups. The original collaboration included the government of Alberta and Professor Lee. The collaboration grew to include the involvement of the Solar Energy Society of Canada Inc.-Northern Alberta

Chapter (SESCI-NAC), which became instrumental to the in-depth exploration of solar design. Numerous individuals representing industry including engineers, environmental scientists, material technicians, and tradespeople provided expertise on an informal basis. In this way, the sustainable redesign of a flat-plate solar collector became a trans-disciplinary collaboration between designer, government, industry, and product users.

By engaging in a project that involves multiple voices and a more holistic approach, exploration can occur on many levels involving a variety of issues in the design process. The redesign of solar collectors is a project that examines issues of solar collection and its relationship to

the methodology of sustainable design. This project encompasses a range of concerns from specific design details to broad principles. Specific design details include combining aspects of product design, communication, instructional, and packaging design. Broad principles include examining the nature of design research, engaging in user-centered and participatory design, which leads to greater user-sensitivity in design and evaluative design. These broad principles also consider sustainability which includes: design ethics, ecologically sensitive material selection, product endurance and longevity, and extended product responsibility. The complexity of this project provides a challenging and stimulating exercise in integrating design theory and history with the practice of product design.

“Dynamics are strong mutual interaction (or feedback) between components.”

Figure 11: Manuel De Landa, 1997.

¹ Kumar, S. “Ergonomics” *REHAB 476 Course*, (University of Alberta, Edmonton. Jan-Apr. 2000).

² Gertsakis, John, Helen Lewis, and Chris Ryan. *A Guide to EcoReDesign—Improving the Environmental Performance of Manufactured Products*. (Australia: The National Centre for Design at RMIT University, 1997) and Gertsakis, John, Nicola Morelli, and Chris Ryan. *An Introduction to Extended Producer Responsibility—Case studies showing how manufacturers are avoiding waste and recovering resources through product take-back*. (Australia: The National Centre for Design at RMIT University, 1998).

³ Mackenzie, Dorothy. *Green Design—Design for the Environment*. (London: Laurence King Publishing, 1997).

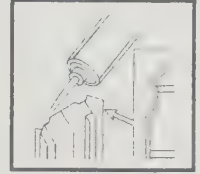
⁴ Suzuki, David. *The Sacred Balance: Rediscovering Our Place in Nature*. (Vancouver: Greystone Books, 1997). McDonough, William. *The Hanover Principles—Design for Sustainability*. (Virginia: Author, 1998). Hawken, Paul. *The Ecology of Commerce—A Declaration of Sustainability*. (New York: Harper Business, 1993) and Hawken, Paul, Amory Lovins, and L. Hunter Lovins. *Natural Capitalism—Creating the Next Industrial Revolution*. (Boston: Little, Brown and Company, 1999).

⁵ Bras-Klapwijk, Remke M. *Adjusting Life Cycle Assessment Methodology for Use in Public Policy Discourse*. (The Netherlands: Universal Press, 1999) 19-29, Charter, Martin and Ursula Tischner, eds. *Sustainable Solutions—Developing Products and Services for the Future*. (UK: Greenleaf Publishing, 2001) 263-281. Gertsakis, John, Helen Lewis, and Chris Ryan. *A Guide to EcoReDesign—Improving the Environmental Performance of*

Manufactured Products. (Australia: The National Centre for Design at RMIT University, 1997) 15-24, and Curran, Mary Ann. *Environmental Life-Cycle Assessment*. (New York: McGraw-Hill, 1996).

- ⁶ Bruckmeier, Karl. "Transdisciplinarity for the Human Adaptation to Complex Changes". Lecture based on same-titled paper by Hans Egnéus and Karl Bruckmeier. *Sustainability and Democracy--The Eleventh International Conference of The Society for Human Ecology*. (Snow King Resort, Jackson Hole, Wyoming, October 18-22, 2000)

The design problem: definition, and goals



The flat-plate solar collector is a known product, yet it has not saturated the consumer market. The availability of solar products in Canada and North America is relatively limited. There is only one Canadian manufacturer of flat-plate collectors, which is Thermodynamics in Nova Scotia, and only one distributor Taylor Munro in Vancouver. The goals of my design include optimizing the thermal properties of materials, material performances, and product performance. In addition, there are different types of solar products ranging from technically very complex to much simpler solar technologies.



Figure 12: *Solar grain dryer*

There is a need for a flat-plate solar collector that is more easily understood by the average homeowner in order to integrate this product into the consumer market. The flat-plate solar collector, is a relatively easy-to-understand solar product, perfect for redressing the misconceptions about the perceived technical barriers in solar products.

This project is ideal for applying the principles of sustainable design and the cradle-to-cradle methodology for three reasons. First, the project redesign is supported by a number of individuals who provide a community for collaboration. The collaboration with Tang Lee, SESCI-NAC, and Climate Change Central provide the opportunity for employing a variety of information gathering methods. These methods, or 'design research techniques,'¹ represent the evolving practice of industrial design. Design research includes several modes of ethnographically-styled information gathering systems. It is important to note that these methods of information gathering do not analyze modes of human behavior, but are used to create an informal structure for gathering tangible and intangible information. This information is then used to direct the



Figure 13: *Solar panel construction workshop*

design process. The research methods include informal interviews, questionnaires, workshops, focus groups, brainstorming sessions, and lectures (see Appendixes 1, 5, 6). Other methods also used included collaborating with appropriate professionals to gain and exchange expertise necessary for working towards product outcomes, and

exploring with user-groups the potential characteristics desired in particular products. Design research is a multi-dimensional process in which the designer engages with many groups and individuals in order to make informed design decisions. The second reason this is a good product with which to develop sustainability is that solar products must be considered within a broader framework than just the technical. Research here includes background reading, informal interviews, and field trips to various solar installations (see Appendix 1). There is a need for a broader analysis of solar collection including the tangibles and intangibles of design, and the environmental and human consequences of solar products. The third reason for choosing this project is that by using the sun as a renewable resource, the flat-plate solar collector promotes the idea of sustainable living. The redesign of a product that considers the environment and also supports environmental values will have an advantage in the marketplace. In addition, a sustainable redesign can be marketed as being 'green' which further layers the advantage of the redesigned flat-plate solar collector.²

The following primary goals were established at the onset of the project:

1. reducing the cost by simplifying the manufacture and assembly of the flat-plate solar collector and the system connection design
2. analyzing and understanding the technical properties of the materials necessary for a solar collector, especially to accommodate thermal expansion and contraction
3. creating a functional and efficiently performing product in colder climates
4. creating a user-friendly product by designing a self-assembly kit with detailed assembly instructions
5. creating a stronger connection between the users of the product

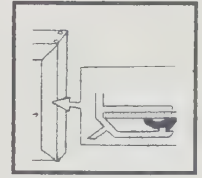
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6. having a flexible-use solar collector that has the following features: usable domestically or commercially; functioning as a liquid or air heater and, a solar heating system that can be a draindown, thermosyphon, or a closed-loop system
 7. creating a product that is easily integrated into a building design and can accommodate new installations and be retrofitted onto existing buildings
 8. creating a product that supports sustainable living and sustainable manufacture

User needs are paramount in designing any product since it addresses the product-people relationship, which is the primary role of the industrial designer. User needs include the function of a product, the aesthetics of a product, and the way a product makes people feel. The established goals are a reflection of these needs. In addition to the user group, the designer is influenced by the client, manufacturer(s), technicians, material producers, and marketers. These are examples of the players in industry who directly or indirectly influence the outcome of a product. There is a specific user group (home-owners), and a specific client (SESCI-NAC) who have varying interests in this products outcome. SESCO-NAC is interested in manufacturing the finished flat-plate solar collector in the near future. Therefore, the sustainable design of the Lee solar collector is defined by the user group and the client. In this way, the redesign of a flat-plate solar collector is a real project that is grounded in reality.

¹ Cross, Nigel, ed. *Design Participation*. Proceedings of the Design Research Society's Conference (Manchester: Academy Editions, September 1971) and Kelley, Tom and Jonathan Littman. *The Art of Innovation*. (New York: A Currency Book, 2001).

² *Eco-design for Competitive Advantage*. First Regional Conference for Manufacturing Companies. The Centre for Sustainable Design. (London. June 29, 2001).

History of solar products: industry and solar failure



Solar collection is not a new technology. It has been around for centuries¹ and has been of particular interest to architects, designers, and the public in times when fossil fuels have been expensive or unavailable. The use of solar power is considered an alternative energy source since it has not been adopted by mainstream consumers. Research in developing solar products over the past three decades has



Figure 14: PV panels on the Regina Science Centre

primarily focused on the technical components involving the most effective ways of gathering, storing, and making use of the sun's energy. Engineering has been the major force behind the design of new solar products—considering efficiency and using logic in the problem-

solving process.

There are essentially two kinds of solar technologies: passive and active. Passive solar refers to design features in a home that incorporate heat collection, storage, and heat release into a structure and do not require any mechanical intervention. For example, the Trombe wall, credited to French engineer Felix Trombe, is a blackened south-facing wall that collects the sun's heat during the day and then radiates the heat at night. Active solar requires an auxiliary system since the units will not work without switches, pumps, blowers, or mechanical devices. The most well-known active solar collection devices are photovoltaic (PV) systems which transform the sun's energy into electricity. Photovoltaic cells were first invented by Bell laboratories in the early 1950s. They are a spin-off technology of transistors, made up of thin layers of pure silicon. When exposed to sunlight, small amounts of electricity are produced. In the 1960s, PV was used for the US space program in satellites. At that time, the cost of PV electricity production was

approximately \$65,000 per watt and today, the cost is approximately \$10 per watt. PV modules convert 6-15% of the received sun's energy into electricity. PV systems operates on a direct current (DC) system; this means that most PV systems require an inverter to convert DC to alternating current (AC). PV panels work best when they are positioned perpendicular to the sun. The use of a tracking device can add 35-50% to the incoming power. Batteries are required for electricity storage thus making it an indirect conversion technology. The average cost for a PV system is between \$10,000 and \$40,000. The cost, battery storage, and strict electrical codes make the PV system unappealing to many consumers.



Figure 15: A Zomeworks PV panel tracker at Kelln Solar, Lumsden, SK.

Flat-plate thermal solar collectors are also considered active systems because they involve heat transfer and have moving parts. The flat-plate collector directly converts the sun's energy to heat which simplifies and reduces the number of components and increases people's ability to understand the technology. Flat-plate collectors can convert 75-85% of the received sun's energy into heat. In addition, flat-plate solar collectors are much more cost-effective than PV systems. A liquid heating system can cost between \$3000 and \$5000 installed.

Flat-plate collectors are built on the principle of greenhouse boxed trays with a liquid-type collector containing pipes with black absorber plates to absorb the sun's rays. There are two ways these thermal solar collectors move the collected heat: liquid or air. In the case of liquid, water or glycol flows slowly through pipes in the collector. The liquid is heated and taken to a storage tank where it is used directly or run through a heat exchanger to heat other water. In air collectors, the flat-plate collector contains a sheet of black metal which acts as an absorber panel. Air is drawn through a space in the panel where the hot air rises and is then blown into a space or heat-absorbing material like concrete. Heat loss and storage are important considerations for an efficient solar collection system.

Typically, single panels are available for either air or liquid heating. In all commercially available products, liquid heaters and air heaters are completely different



Figure 16: HETH flat-plate collector

products. Insulation in the collector prevents the converted sunlight from escaping and insulation on the pipes in the transfer system maximizes the thermal transfer into heat.

A flat-plate solar collector does not replace a conventional heating system—it supports it. A back-up system will be necessary due to daily sunlight fluctuations, seasonal shifts, and varying daily times of heat consumption. Flat-plate collectors absorb both beam and diffuse radiation, and radiation reflected from the ground or surroundings.

Beam is the part of the solar radiation which casts shadows. Diffuse radiation is reflected and scattered by clouds and dust before it reaches the ground. A collector in a solar heating

system therefore operates over a wide range of conditions during a year. It is estimated that, on average, a flat-plate solar collector can provide up to 75% of a household's heating needs.² It is a misconception that solar collectors do not work well in colder climates. Detailed investigations have shown that Edmonton and the province of Alberta are excellent collection locations³ allowing for maximum collection in the coldest months of the year. It is important to orient the collector(s) vertically on a south-facing exterior wall and make the most from snow cover reflection because flat-plate collectors can absorb a range of radiation types. By making use of diffuse radiation reflected from the ground, it increases collection during the winter months (note Figure 10). Under a wide range of conditions, a flat-plate solar collector may run very hot at times, and it also runs cooler at low efficiency⁴, but is nonetheless worthwhile 12 months per year.



Figure 17: The Saskatchewan energy conservation house, 1978.

The benefits from having a thermal solar collector can be enormous. Any structure that requires heat can use an air-heating device. A liquid heating solar collection device is particularly useful for applications such as for domestic use, swimming pools, shower rooms, and cafeteria settings. Any thermal solar collecting system reduces the amount of fuel used for heating purposes thereby saving money and conserving natural resources.

Documentation of the Canadian solar industry began in 1978 when Public Works began three federal programs to assist in producing energy self-sufficiency and conservation of renewable energy sources. The three programs were *Purchase and Use of Solar Heating* (PUSH), *Program of Assistance to Solar Equipment Manufacturers* (PASEM), and *Low Energy Building Design Awards* (LEBDA). From 1978 to 1981, Public Works shared costs of 500 PUSH projects, subsidized 10 Canadian solar equipment manufacturers, and presented 34 winning designs. Included in these were small domestic projects such as a drain-down water heating system at Dick D'Alquin's home on a west Edmonton acreage and a million-dollar refrigerator railcar washing facility for Canadian National Railways (CN) in the Calder Yard in North Edmonton. This drain-back liquid heating system had 96 evacuated tube panels designed by Dow Corning, manufactured by Sunmaster, and installed by Solartech. The D'Alquin system paid for itself by 1987 and is still in operation today. The CN system never worked properly and only operated for approximately six months (see Appendix 1).

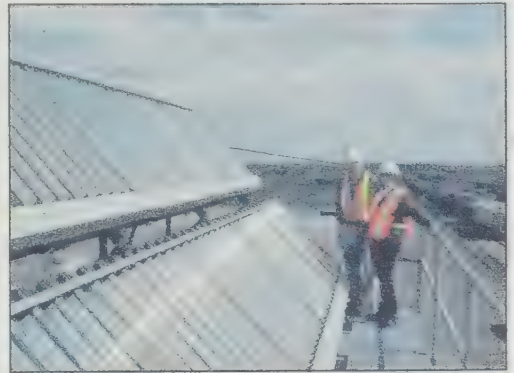


Figure 18: CN Railyard railcar washing facility

In the US, government solar energy support programs date back to the 1940s. After the Organization of Petroleum Exporting Countries (OPEC) was established October 1973, there was a marked increase in government funding in 1974, due to the US's dependence on foreign energy suppliers. Three primary goals were established for the US National plan for solar heating and cooling:

1. to demonstrate commercial and residential systems
2. to provide a financial support system for these demonstration projects
3. to research and develop solar heating and cooling technologies

It was perceived that the barriers to using solar energy were cost, reliability, and regulatory constraints. Between 1920 and 1977, \$22 billion US went into developing the solar industry. Between 1979 and 1985, another \$65.4 million US was spent on solar programs. A great deal of research and development funding was given to government agencies, government laboratories, and universities. In 1986, funding was cut by the Reagan administration.⁵

The failures in the solar incentive programs of both Canada and the US are not due to lack of funding. In fact, it may have been excessive funding that drove solar into a technical realm, untouchable by the average person. The incentive programs seemed to be designed to produce sales but they did not assure continued product support. Additional flaws in the government funding programs were lack of field monitoring, testing and standards, and public information dissemination. Furthermore, not many of the quality improvements found their way into the market before funding ended. In researching past and contemporary contributions to the solar industry, I discovered that most paints, pumps, controllers, and monitoring devices are no longer available. The solar industry was never self-sustaining since it relied heavily on government funding—solar products were treated as prescriptive solutions to fossil-fuel depletion. Of the 10 solar equipment manufacturers in Canada, none of them are now in existence—all of them having gone bankrupt shortly after funding ended. This is an increasingly difficult problem with solar today. There are few support networks that are tried-and-true. Many contractors and manufacturers were considered fly-by-night and often left the owner of a solar collection system with insurmountable design problems, which was the case with the CN Calder railcar washing facility.

“All structures that surround us and form our realities...are the products of specific historical processes.”

Figure 19: Manuel De Landa, 1997.

In reaching an understanding about contemporary solar collectors and their history, I began an exploration of solar failures in Alberta and Saskatchewan.

Unfortunately, the failed systems outnumbered the working ones. I discovered that systems failures are most often traced to improper installation including poor mounting, inadequate hangers for plumbing, and inadequate consideration for thermal expansion and contraction. In addition, failures relate to non-solar specific components such as pumps, valves, and controllers. Interestingly enough, solutions to many of the problems of solar heating systems do not require advanced research or development of exotic new materials. These problems can be resolved by proper thermal design, production details, and simplification of solar collectors and systems connections. I believe that the government incentives were not only unsuccessful in creating a sustainable market for solar energy technologies, but they were also harmful to the very industries they were intended to promote. The process needed to be fundamentally better than maintaining the present economic situation. Implementation of solar collection devices such as the flat-plate collector should be more than the purchase of equipment. Solar collection systems require maintenance, just like any other device. These collectors/products need to deliver energy and educate the end-user about this technology and environmental issues. The new history of solar use is being written by the redesign of a misunderstood product.

¹ Butti, Ken and John Perlin. *A Golden Thread—2500 Years of Solar Architecture and Technology*. (Palo Alto, California: Cheshire Books, 1980) 2-59.

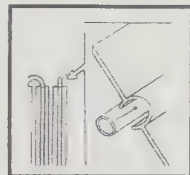
² Schiffman, Yale M. and Gregory J. D'Alessio. *Limits to Solar and Biomass Energy Growth*. (Toronto: Lexington Books, 1983).

³ McKay, D.C. and R.J. Morris. *Solar Radiation Data Analysis for Canada 1967-1976—The Prairie Provinces*. Vol. 4. A Publication of the Canadian Climate Program, Minister of Supply and Services Canada. 1985 and Campbell, A., ed. *A Tabulation and Analysis of Solar Radiation Data from Alberta*. Edmonton: Alberta Research Council, August, 1977.

⁴ Beckman, William A., Sanford A. Klein, and John A. Duffie. *Solar Heating Design by the F-chart Method*. (New York: John Wiley and Sons, 1977) 11-12.

⁵ Frederick H. Morse in Beattie, Donald A., ed. *History and Overview of Solar Heat Technologies*. (London: The MIT Press, 1997) 137, 159.

Design criteria: technical and sustainable



The development and design of a flat-plate solar collector begins by identifying the design problems and defining the objectives within the context of solar products.

Design criteria in this case have been established through the exploration of context which includes sustainability and the history of solar use. Understanding where solar technologies have been helps to create a checklist of where it needs to go. Most designers are taught to explore similar products currently available on the market. Through gathering this information, the designer either improves on those products or creates something that is competitive in the marketplace. By looking further back at history, the designer can give her/himself an edge by integrating a broader range of design information.

Through background readings and field visits, I was exposed to a broad history of solar use. Two significant studies on solar failure were completed in North America in the late 1970s. The US government¹ reported on material performance in 1977 and in 1978, and the government of Canada² reported on operating solar systems. In addition to these reports, I conducted field research and documented solar failure at a number of sites in Alberta and Saskatchewan. From this study, I noted recurring problems in flat-plate solar collectors and systems connections. The choice of materials is paramount. Dissimilar metals cause galvanic action and result in a short product lifespan. Many materials are not designed for the extreme conditions of a collector. For example, glazing can melt, buckle, and discolour. The interior environment of the collector is vulnerable to condensation, which can reduce heat storage. Some material use can decrease the product's efficiency and be hazardous, such as wooden frames, which can become dry and could catch fire (see Appendix 8). Failure in liquid-heating solar collectors in North America is particularly high. There have been many home-made collectors since the 1970s. Specific design flaws noted in the field provided me with a better understanding of solar technologies. Tempered glass is typically used, which shatters easily and is vulnerable to vandalism, particularly in public places. Most panels designed in the late

1970s through the 80s were completely sealed with no options for maintenance. The result is panels that are taken apart and “jimmied” back together, destined never to function properly again. Overall panel design does not take into account the weather conditions of a particular location. For example, heavy winds in the prairies can result in complete panel destruction.

Doug Lorriman wrote:

“...it cannot be assumed that a collector designed to meet conditions in Regina will work without difficulty in St. John or that a collector imported from New Mexico will be suited to the conditions in Toronto. All aspects of the local environment must be taken into account when component design and installation decisions are made.”

The final design criterion for this project is to design locally for this particular geographical situation. Even within Alberta, there is a vast range of meteorological conditions; however, in order to design an appropriate product, these conditions must be part of the equation.

The result of my background research is to develop a multi-factorial systems approach to the design of solar collectors. This approach includes balancing, not compromising, the following:

- 1) functional properties including thermal qualities, relatively narrow operational tolerances, stagnation conditions, moisture penetration, high pressure conditions, high temperature conditions, high humidity conditions
- 2) compatibility properties including how materials affect each other, for example, corrosion potential
- 3) environmental response properties including how materials endure exposure to the outdoor environment of weather and air pollution, and how materials endure temperatures within the system, for example, freeze-to-leak potential and material degradation
- 4) hazardous properties have health and safety implications which include material off-gassing, contamination of potable water supply, and a need for fire resistance
- 5) environmental impact properties or life cycle cost analysis of individual components and the finished product, including impact on soil, water, and air associated with the extraction, production and disposal of materials

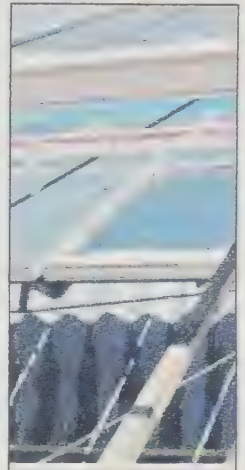


Figure 20: Shattered glazing at Killam, AB recreation centre

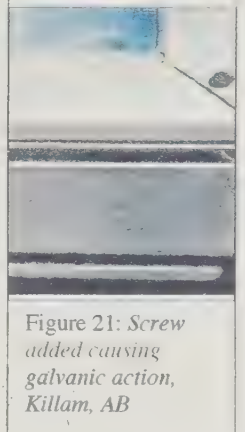


Figure 21: Screw added causing galvanic action, Killam, AB

“It is logical and natural to produce, consume, and organize as locally as possible.”

The industrial designer is accustomed to considering many factors in the manufacture of a product. These will vary depending on the client and the desired outcome. In this case, the redesign was imbedded with client concerns, user concerns, and personal goals:

- focusing on the solar collector with consideration to the system connection
- establishing that the primary use would be in residential homes and that the user-group would be the average home-owner
- creating an economically feasible, cost-effective, potentially excellent payback-cycle solar collector by reducing manufacture costs and installation costs
- maintaining and exceeding known technical advances of solar domestic hot water systems and hot air systems in terms of durability, material use, performance, and product efficiency
- considering the need for continual servicing including installation, maintenance, troubleshooting, and emergencies
- improving reliability and understandability of the flat-plate solar collector

In applying the principles of sustainable design, there are many considerations that an industrial designer finds familiar like design for lightness, minimal material use, and design for disassembly. However, the added aspect is the cradle-to-cradle methodology that includes the environment on a biophysical level, making it both challenging and enlightening. Specific details about the sustainable component of the design process include:

- eliminating all hazardous materials by using non-toxic, environmentally-friendly products wherever possible, for example, assessing the available materials and indicating recommendations based on performance and hazards
- using native materials, for example, working with local manufacturers to develop new products
- working with local companies to manufacture necessary components, for example, feasibility of creating the various components in the province
- working with local companies to attain necessary components for system connection and reduce transportation costs, for example, the development of a standard kit for system connection that can be ordered and packaged by one company in Western Canada
- using natural materials, renewable materials, or materials with high recycled content, for example, exploring the options for all materials and indicating recommendations based on present availability or perceived future availability

- using materials appropriate to industrial manufacture that consider performance and durability, for example, exploring materials based on their performance data for the flat-plate internal environment and the Western Canadian meteorological environment
- minimizing use of materials, for example, reducing the number of different materials and the actual weight of materials
- anticipating the re-manufacture and re-use of components, for example, design for disassembly where the product is as easy to take apart as it is to put together
- predicting change or anticipation of future modifications to the design—due to general wear and tear, or change in technology, trends, for example, optimizing tolerances for ease of assembly/disassembly in order to replace components as needed
- considering transportation costs as impacting the environment, for example, working with local companies when feasible

The above design criteria are complex and challenging. It is not possible to approach this design problem in a formulaic way because the criteria overlap and sometimes even conflict. With a product such as the flat-plate solar collector, it must first function properly; therefore, the thermal limitations of materials are ultimately the first concern. Thus, the design criteria are defined first by user needs, including function, and finally, by the principles of sustainable design.

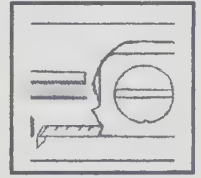
“A complex structure consists of a hierarchy of elements.”

Figure 23: Ed van Hinte, 2001.

¹ Skoda, L.F. and L.W. Masters. *Solar Energy Systems—Survey of Materials Performance* (Washington: National Bureau of Standards—Energy and Research and Development, October 1977).

² Lorrman, D. *A Study of Some Problems in Operating Solar Systems*. (Toronto: National Research Council of Canada, July 1978).

Product redesign: material selection and design details



Western industrialized societies' approach to industrial design has been predominantly material, with a focus on analytical and logical design. This kind of design has perpetuated a desire for having more objects and for objects that create a sense of status. The redesign of a flat-plate solar collector begins to challenge the North American status quo by exploring a variety of design concerns—human, technical, material, and environmental. The flat-plate solar collector I have redesigned has the following features:

- easy assembly and installation
- assembly that can be done by one or two people
- easily integrated into a building design
- accommodates new installations and retrofitting onto existing buildings
- functional and efficiency performance in colder climates
- all components accommodate thermal expansion and contraction
- has provision for a drain-down system
- can be used as an air or liquid heater
- cost-effective with a three- to five-year payback
- locally designed and manufactured in Alberta
- supports sustainable living and sustainable manufacture

Non-western cultures, such as East Indian, are less materialistic and more reliant on spiritual values¹, one of the intangibles of design. There is a greater recognition that the intangibles of design can exist through integrating the spiritual and emotional aspects of humanity by creating embedded meaning.² This concept can be incorporated into a sustainable design model to create an evolving relationship between products, the built environment, and the user. Since the 1970s, sales strategies have involved the idea of using people's individual experiences in product marketing. For example, Sony capitalized on 'lifestyle' concepts by targeting potential people who would use the Walkman. Taking the concept of creating products with meaning one step further, it draws upon humankind's basic desire to create

experience, story, myth, and symbol.³ As examples of embedding intangibles into objects, Mahatma Gandhi created value in ordinary tools and simple clothing by drawing upon everyday experiences and myths of the Indian people. He single-handedly created value and multi-dimensional messages in products to guide the Indian people towards self-determination. He created a bridge for ordinary people by embedding meaning—taking products beyond the image of their original creator and making them more meaningful. The designer need not rely on the user to create meaning from products; those products can be scripted like movie characters but scripted with a sense of experience, myth, story, symbol—this is called creating product longevity.⁴ Just as each character in a movie is scripted, artifacts must have the same kind of script.⁵

Many intangibles of design are not immediately visible in a product, just as many sustainable materials used for construction are not visibly different from their unsustainable counterparts. Information has been gathered about the relationship that people presently have with solar products (see Appendix 1, 6). Because of this, I understand that bringing a new energy technology to the marketplace requires more than technology. Several books on the history of solar use echo this thought.⁶ It is clear that in order to make the solar product appealing and for it to have more value to the average home-owner, there need to be a number of designed-in elements that provide experiential relationships with the solar collector. People need to be connected to the product on as many levels as possible—through sense of touch, sight, and experience. Design solutions implemented in the project that incorporate these ideas are:

- Creating an experiential relationship with the product by providing an easy-to-assemble kit that is pleasurable to construct. This provides the owner/builder with a deepened sense of commitment to the solar collector since s/he has constructed it personally. Instructions for assembly have been carefully designed to consider clear communication (refer to the included CD and/or assembly leaflet).
- Reducing the solar collector's size and providing a uniform shape when in kit format, making it easier to handle and flexible to configure in arrays.
- Providing the option to custom-design the solar panel shape to fit specific locations, for example, a triangular panel to accommodate a gable of house or garage.
- Creating the option to enhance the aesthetic of the flat-plate collector by using the glazing as a canvass to apply colour, imagery, or patterns on that

face. The image could be provided or one that the user could choose. The glazing film that is available to-date, is a 3M product with a temperature resistance above their other available films. The design of this product and its use is still in the experimental stages and must be tested for durability related to heat resistance and for the exact amount of solar radiation that is blocked from the film.

- Providing a user manual that elaborates on use, regular maintenance, and trouble-shooting systems problems. This manual is combined with the instruction design and includes information on sustainability and material impacts on the environment, aspects that were of interest to the user-group (refer to the included CD, assembly leaflet, and/or Appendix 13).

Creating an experience for users beyond style takes careful consideration. Attention to small design elements is a significant aspect of the product design. These involve taking a holistic approach whereby the solar panel design is supported by an instruction leaflet and packaging design. Creating an easy-to-assemble kit involves an in-depth analysis of how people behave in the creation of flat-plate solar collectors, and how they perceive kit instructions (see Appendix 6). The basic principles applied to this assembly kit are ideas that support the principles of sustainable design (see Appendix 3). These include designing for disassembly, easy maintenance, and repair/upgrade which provides a simplified kit.

The easy-to-assemble kit involves a reduced number of components, materials, and minimal tools needed for construction (see Appendix 9 and 10). Fewer components allow for fewer stages in the construction process. Fewer materials support the potential for recycling and reuse at product end-of-life. By using non-specialized tools for construction, it allows for a greater number of people with generalized skill levels to build the panel.

The assembly instruction leaflet has been designed by analyzing all the stages involved in building a flat-plate solar collector. Some of these may seem obvious to the more experienced builder, but leave less room for misinterpretation of the stages of construction. The instruction leaflet has line drawings that accurately represent the actual components for ease of recognition. The outside packaging of the kit clearly indicates the tools needed for construction to assist users in assessing whether the kit is within their skill level and which tools are not included in the kit.

In designing an easy-to assemble kit, the size and shape of the solar collector becomes very important. A manageable size reduces the overall size and weight of the collector and allows

for fewer people to be involved in the construction process. A 4' x 4' panel provides a 4' x 4' x 16" overall package size with an estimated weight of 60 pounds. One individual can easily construct the kit.

There are two potential solar collector kits—one for air heating and one for liquid heating. The instruction leaflet for the liquid heater has been designed since it is more complex than the instructions would be for an air heater.

In addition to designing a kit, the frame extrusions can be configured into any custom-designed shape required. In this case, the individual components would be purchased in a non-kit form. Another potential custom design feature would be turning the flat-plate solar collector into signage. A glazing film with a printed colour, pattern, or image enhances the aesthetic and alters the function of a flat-plate solar collector. The ability to collect heat may be compromised up to 50% but for a commercial sign to be 'producing' rather than just 'consuming' is very exciting. I imagine liquid or air heating collectors in the shape of the golden arches interacting sustainably with a nearby structure.

Small design elements, such as those described above, begin to consider an aspect of design that has been neglected in many products over the past several centuries. The human desire to embed aspects of need beyond the material provides stronger product meaning, rather than clinging to the illusions of glamour and sleek designs.

In terms of the material aspect of design, the primary characteristics of a good flat-plate solar collector are its ability to absorb, store, and distribute energy. The principle cause of solar failure is the selection of unsuitable materials; therefore, it is necessary to carefully design with materials that are appropriate for this application. There are many materials that do not possess desirable properties for this application. In the extreme situation, the interior environment of the collector can be above 100°C with outside temperatures being below -30°C. In these cases, the interior of the collector will naturally equalize to the outside temperature during the night. This indicates that the materials used for the collector must be extremely resilient to thermal cycling. In addition, the cradle-to-cradle approach recognizes that each component of the solar collector must be scripted from beginning to end. This approach parallels 'birth, life, death, and reincarnation'. It addresses the past—considering the extraction and

manufacture of materials, the present—considering the needs of clients and user-groups, and the future—considering disassembly, disposal, and reintegration of the product (see Appendix 8 for details on the material selection process).

The extreme demands for heat resistance eliminates many families of materials. For example, there are few plastic products available that can fulfill these requirements. Companies like *Dupont* and *Dow Chemical* are continually researching and developing plastic products that will perform under radical thermal conditions, but they have not found solutions to all design needs (see Appendix 7—plumbing). Plastics are synthetically produced polymers, which vary in formulations and conditions. They ‘creep’, which means that they continually deform at a slow rate indefinitely. Because plastics were designed to easily change shape using very little heat, generally, they are not durable in extreme temperatures. They become brittle at low temperatures and combustible at high temperatures. Plastics have a 2-10 times larger thermal expansion capability, which makes design for tolerances critical. Some thermoplastics such as polycarbonates (PC) can handle the thermal cycling since they do not melt; however, they undergo some surface deterioration, cracking and warping. Lexan, a clear, amorphous PC that has exceptional toughness over a wide temperature range, has dimensional stability and is weather- and UV-resistant and could potentially be used for glazing (see Appendix 7—glazing). In addition, plastics traditionally replace other materials because they lower the cost of manufacturing and the weight of a product. However, that cost equation does not include the environmental damage that can result from the disposal of plastics. Thermoplastics can be recycled with ease and recycling for thermosets is beginning to be done. Thermoplastic can be reground and reused but this requires a complex labeling and sorting system for recycling since there are so many varieties of thermoplastics. The North American marketplace needs to improve in the area of labeling to make plastic recycling viable. Many groups of plastics are difficult to recycle and most are created from hydrogen, carbon, nitrogen, oxygen, fluorine, silicon, sulfur, and chlorine atoms—all which are derived from oil, a non-renewable resource.⁷ Plastics make up 1-3% of municipal waste in open dumps, sanitary landfills, incineration, and recycling.⁸

Another family of materials that was deemed inappropriate for this product design is composites. Composite materials are two or more materials that are bonded together to form a new product. It is impossible to separate the materials after they are bonded. An example is automotive fiberglass and resin, which has been used over the past century because of its durability and ease in creating organic forms. Composites are considered to be environmentally-unfriendly because they cannot be recycled or reconfigured at the product

end-use. An example of a composite product is the *Thermodynamics sunstrip* absorber plate, which is made by bonding aluminum to copper. One benefit to this design is that it is lightweight, but the drawbacks are that it is a composite that requires very specialized equipment in the manufacture process. In addition, the design cannot be improved upon because the equipment that creates the product cannot be reprogrammed to create it differently. In following the cradle-to-cradle approach in sustainable design, designing for change and considering future possibilities are key principles.



Figure 24: A copper and aluminum composite absorber plate

“Energy cannot be created or destroyed, merely changed from one form to another.”

Figure 25: Ernest Callenbach, 1998.

Further criteria for selecting materials are how they absorb and distribute energy. Two things occur with energy absorption and distribution. First, there is an increase in temperature and second, once the materials attain a certain temperature, they begin to change phase by distorting or melting. It is generally understood that materials radiate heat; however, their ability to conduct heat is indicated by the thermal conductivity—the amount of energy transferred across a material. In addition, corrosion or other forms of breakdown can occur in materials due to heat and general wear-and-tear or through chemical reaction.

Compatibility of materials is another criterion for material selection. Some materials are simply not compatible with others; for example, EPDM rubbers are not compatible with PCs (see Appendix 7 – rubber and glazing). Material compatibility in a

flat-plate solar collector product is also a major consideration since there are extreme temperatures and moisture build-up. For example, steel and aluminum are chemically incompatible and create damage, reducing the life of the product significantly. In the case of dissimilar metals, this is called galvanic action. Galvanic action can occur when two metals come in direct contact with one another or when metals come in contact with a common fluid. In the liquid-heating flat-plate solar collector, certain components are in constant contact with liquid. Not only is it important to choose the materials that can withstand thermal expansion, contraction, and extreme environmental conditions, but also ones that relate to each another in a positive way (see Appendix 8).

There has been a growing interest in exploring materials and manufacturing in the North American design community because of the variety of materials now available to design with. For this project, it was important to research a wide range of possibilities in an attempt to find the perfect material for each component of the collector. During this process, I encouraged companies to develop materials that would fit the needs of the solar collector. For example, I realized there was no suitable insulation available for solar collectors. As a result, I worked with *Ayr-Reflective* in Quebec and developed an insulation that more appropriately matched the thermal requirements (see Appendix 7 – insulation). This represents the power of the industrial designer in the free-market economy. Businesses are eager to please and be profitable. *Ayr-Reflective* is now interested in marketing the product that was developed because they see its potential use in a variety of applications. It is in this type of situation that industry collaboration occurs. The designer with an environmentally-conscious attitude can make a difference in requesting products that fulfill more than just the basic design needs.

“In an age of mass production when everything must be planned and designed, design has become the most powerful tool with which man shapes his tools and environments.”

Figure 26: Victor Papanek, 1971.

In analyzing the components of the liquid heating flat-plate solar collector, I defined eight distinct categories of parts and the specific functions they perform. They are as follows:

1. **Frame:** The frame acts to hold and confine the other materials in their designated places within the solar collector. It can also reduce heat loss from the collector and allows heat to build up within the unit. The frame is screwed together at each mitered corner to create a uniform shape.
2. **Glazing:** The glazing acts to protect the collector while allowing solar energy to pass through it. The glazing also helps to reduce heat loss. Glazing film can be used to decorate the panel.
3. **Insulation:** The insulation acts to retard the flow of heat from the collector and other subsystems to the ambient environment. Insulation is located on the back of the panel and in the frame. Insulation is also located on the transfer pipes and the storage tank of the solar collection system connection.
4. **Pipes:** The pipes act to absorb energy and to transfer the heat to storage. Pipes are only present in a liquid-type collector. In the case of an air collector, ducting acts in a similar way.
5. **Absorber Plates and Coatings:** The absorber plates 'hug' the pipe and are often one with pipe, such as with the *Thermodynamics sunstrip*. The absorber plates absorb solar energy and convert that to heat. With an air collector, the absorber plate is made from a sheet material, such as galvanized steel. In each case, the plates are covered with flat-black paint (or another dark colour) in order to absorb as much solar energy as possible.
6. **Backpanel:** The backpanel is not visible when the solar collector is mounted. However, it acts to contain the insulation and prevent heat loss. The backpanel may also stabilize the solar collector, keeping it square and protecting the interior components from harm and the siding or roof of a structure from heat and leak potential.
7. **Seals and Sealants:** The seals and sealants act primarily to prevent air flow and heat loss from the panel. In some cases, seals also prevent leakage of the heat transfer fluid. A seal can also act to hold components in place, such as the glazing. In addition, seals can create thermal breaks when there is a need to prevent heat from transferring from one component to another.
8. **Heat Transfer Fluid:** The transfer fluid can be air or a liquid such as water or anti-freeze, and acts to absorb heat from the collector tubes and absorber plates. The transfer fluid can potentially cause corrosion in the system. Therefore, it is critical that it be chosen wisely.

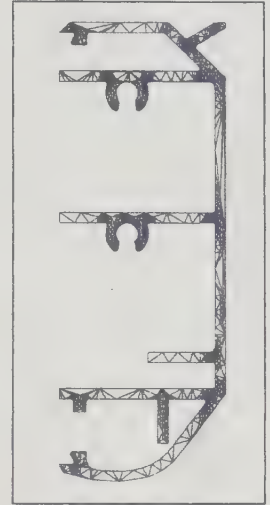


Figure 27: An early version of my extrusion showing polygon meshes

After materials are selected, specific design details are organized according to the above eight categories. Naturally, the manufacturing process is driven by material selection. As mentioned, the selection process for each material was limited in some cases by the technical requirements and in other cases affected by environmental factors (see Appendix 8).

Frame



The material choice for the frame is extruded aluminum, with a preference towards using recycled aluminum stock. There are several aluminum extruders in Alberta and other

Canadian provinces. Aluminum extrusion required heating the metal to between 600°F and 800°F and slowly forcing wrought cylindrical billets, under hydraulic pressure, through steel die openings of desired cross-sections. The steel for extrusion dies is reused indefinitely by most extruders. Alberta extruders typically use 6000-series aluminum in their extrusions. The 6000-series is an architectural-quality aluminum with high elasticity and is corrosion-resistant.

The extrusion process is not complex; however, there are very specific design considerations. The five major factors to achieving a high quality extrusion design are: shape configuration, tolerances, surface finish, alloy, and circumscribing circle size.⁹ I carefully analyzed the design details of the Lee extrusion and discovered that the multi-purpose nature of the extrusion is what makes it unique. It can perform two jobs depending on the user's needs—it can be installed as either an air or liquid collector. Another design

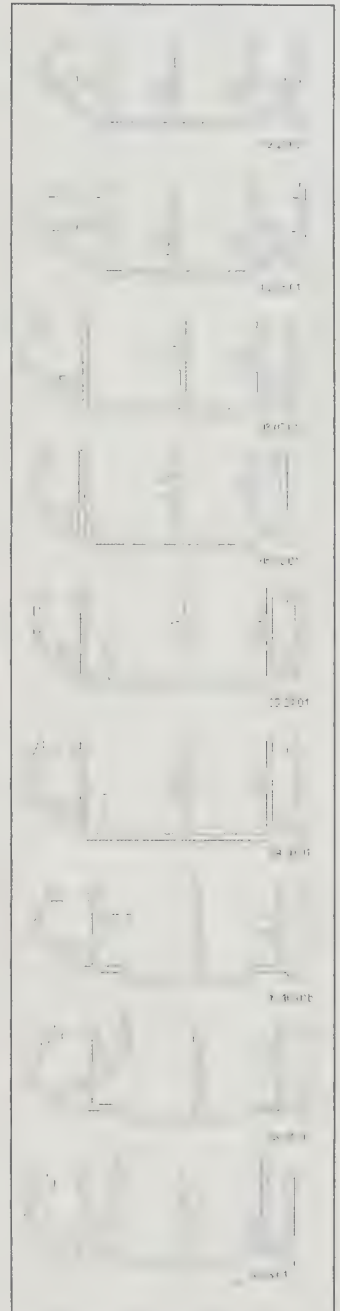


Figure 28: *The evolution of my extrusion design, December 21, 2000 to October 23, 2001*

feature of the Lee frame is that it is a co-extrusion, with an overall structural frame piece and a pressure plate to hold the glazing in place. This allows for the inside of the collector to be accessed from the front of the panel.

The major design change that I felt was necessary was to eliminate the co-extrusion and simplify it to one extrusion. Design for lightness is a new trend in design practice¹⁰ and this would theoretically reduce the amount of aluminum used in the product design, therefore, reducing the weight of the overall panel. It would also reduce the number of necessary components in the panel by eliminating bolts, washers, and weatherstripping for the pressure plate (see Appendix 9). In simplifying the design of the frame, tolerances became very important, since the extrusion needs to perform many tasks at once. For example, it must hold the insulation, the glazing, pipes/absorber plates, allow for air space to prevent heat damage to specific materials (note Figure 31), and be easy to assemble and disassemble. My extrusion design evolved

“...progressive developmental steps, each better than the previous one, and indeed leaving the previous behind.”

Figure 29: Manuel De Landa, 1997.

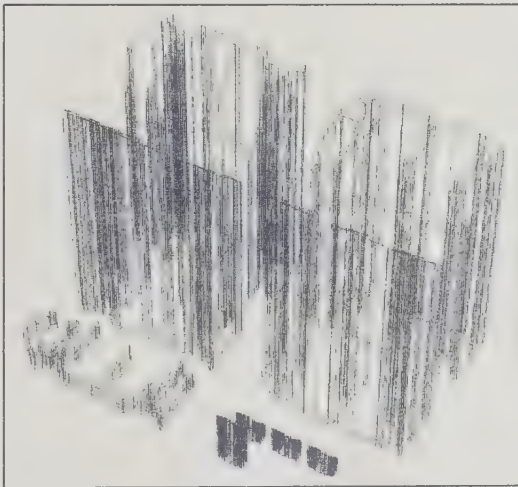


Figure 30: Three-dimensional perspective for rapid prototyping

and transformed over a lengthy period of time because it was necessary to have the extrusion work in co-operation with all other elements in the solar collector. I viewed the frame as the key element to creating a panel that allows the individual parts to work cohesively therefore making an easy-to-assemble unit. The design process was aided by using the *Stratysis* three-dimensional printer to create cross-sections of the mono-extrusion prototypes. Having a rapid prototype guided the design

process as I could carefully measure details and refine them systematically (see Appendix 14 for full-dimensioning).

The characteristics that are embodied in my completed extrusion include:

1. a glazing sleeve that accepts 6 mm glazing combined with a rubber glazing bead
2. screw-in sleeves that are placed 1/2" from the edge of the frame for ease of assembly and screw-in sleeves designed to accept two #10 x 1 1/4" self-tapping screws on each mitered corner, for a total of eight screws per solar panel
3. built-in indexing marks that help to guide the drill bit and make drilling easy; these are for the frame screws, weep holes, and mounting bracket
4. built-in receptor for screw-head make the screws flush with the frame
5. mounting base for backpanel and absorber plates are integrated into the frame, these would be attached with six #6 x 3/8" self-tapping screws for each, for a total of twelve screws per solar panel
6. angled bracket is centrally placed to help in gliding the insulation into place
7. accommodates both air or liquid heating by allowing for the appropriate air space
8. flange is created for mounting the frame onto the structure
9. built-in divets for receiving silicone beads to help hold and seal the glazing and the backpanel in place

(see Appendix 9)

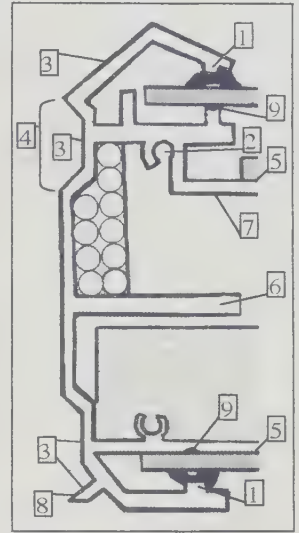


Figure 31: Extrusion cross-section with components.

The solar collector is much easier to assemble since bolts, rivets, and the need for a 'break' to fold the backplate have been eliminated (see Appendix 10). Two sizes of Robertson stainless steel screws are used to prevent galvanic action from occurring. Stainless steel screws are necessary for the frame joints to withstand the rigors of assembly and disassembly.

In designing the frame with only one part, cost savings are extensive when small batches of collectors are manufactured. Batch production also allows for more changes to occur in the design, rather than the design being fixed and unchangeable. One extrusion makes the frame more conducive to assembling and disassembling since it is less complex to handle and has fewer overall parts (see Appendix 9).

The above design details cumulatively represent a new generation in the design of a product from a sustainable viewpoint and the redesign of a flat-plate solar collector from the user's viewpoint.

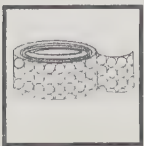
Glazing



The glazing makes up the largest exposed surface area on the solar panel so its properties are specific to the extreme exposures it will face. Glazing must be resistant to surface erosion or marring from wind, dust, and hail. It also must be resistant to UV radiation, degradation by high temperatures, and thermal cycling. Ideally, the glazing will transmit high levels of solar radiation to allow solar energy through, have high reflectance of long-wave radiation emitted by the absorber so energy will be reflected back to the absorber plates, and have low absorbance of all radiation so the glazing will not heat up and cause physical and chemical degradation. Since the glazing on the solar collector must be relatively transparent and comes in a sheet format, there are few choices for material selection.

A single glazing of 1/4" tempered glass is recommended to keep the overall weight of the panel manageable. Liquid and air heating panels can be very heavy; for example, the HETH panel with 3/8" glazing, weighs more than 200 lbs, primarily due to the weight of the glazing. In addition, the overall size of the 4' by 4' panel is driven by the standard glass sheet size (see Appendix 8) and the manageability of a single panel (see Appendix 6). It is a major concern for most people that solar collectors be people-friendly, particularly in a retrofit situation where the home-owner is mounting their own panel. In addition, the flat-plate panels that are typically manufactured are approximately 4' by 8', which is a shape more difficult to configure into an array. With a square shape, the owner has more options of how to configure more than one panel.

Insulation



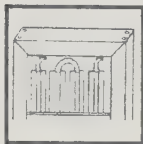
The most common problem with the insulation in a flat-plate collector is the absorption of liquids, which decreases the insulation R-value. Another issue is that the insulation can become a fire hazard since very high temperatures are inherent within the collector box. Fire threat is especially high if a heat transfer fluid such as glycol leaks out into the insulation, since glycol is flammable.

Insulation is required in two locations in the flat-plate solar collector—one is in the frame and the other is on the backpanel. In both cases, the insulation keeps the heat contained in the collector and can also act to reflect heat towards the absorber plate. The frame insulation is especially important since aluminum loses heat as well as it transfers it; thus, heat can easily flow out of an uninsulated frame. The frame insulation needs to be in 1/2" x 1" x 16' lengths and the backpanel insulation needs to be in a 1/2" x 4' x 4' sheet. Due to the significant difference in the required format, two different types of insulation are required. The thermal requirements for the two insulations are also slightly different, with the backpanel one requiring a higher thermal resistance, since it could potentially be in direct contact with the absorber plates if anything shifts inside the collector.

With the requirement of moisture resistance in mind, I sought an insulation that was in a sealed 'bag' or a material that could withstand moisture. There were no products on the market that fulfilled moisture resistance and had the necessary thermal requirements. Initially, I considered cellulose since *Can-cell Industries*, of Edmonton, manufactures two products from recycled paper stock. Their cellulose product has borates as a fire retardant, which is a minimally harmful preservative. A local product that uses recycled materials fit well with the sustainable methodology. After further explorations, I realized that the need for appropriate foil took precedence over the desire for a material with recycled content. After researching many Canadian insulation manufacturers, I discovered *Ayr-Reflective* in Quebec, a manufacturer of foil products. Together we developed a metalized, mylar aluminum foil bag with a *Johns Manville* fiberglass insulating blanket inside. The foil bag is manufactured by *Ayr-Reflective* and is waterproof and recyclable. The *Johns Manville* insulation is manufactured in Innisfail, Alberta and contains 40% recycled bottle glass—the highest recycled content possible to maintain a high quality fiberglass insulation. The *Ayr-Reflective* foil bag keeps the fiberglass out of direct contact with the user until the disassembly/disposal process when the materials can be separated for recycling (see Appendix 7 for temperature ratings on insulation products).

The frame insulation, which comes in appropriate dimensions and is easy to install, is another foil product manufactured by *Ayr-Reflective*.

Pipes



The pipes for the liquid-heating solar collector must be compatible with the plumbing system in an existing structure. Copper is typically used in domestic and commercial plumbing applications in Canada so it is natural to use this in a solar collection system for ease of hook-up. One of my early designs combined the pipe and absorber into one unit that would be extruded in aluminum. This early design was discarded because the extrusion lengths are linear and would need a custom-designed connecting device that would be costly to manufacture. In addition, aluminum is perceived as toxic when mixed with potable water and is soft which makes it less durable.

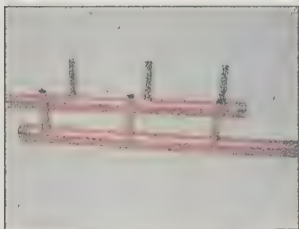


Figure 34: *Manifold-styled plumbing pipes*

Having chosen copper for the plumbing-pipes of the solar collector, the configuration needed to be addressed. Typically, the pipes are configured with an upper and lower manifold of a slightly larger dimension to the joining pipes. In the HETH workshop, there were 46 solder joints between the 3/4" manifold and the 1/2" absorber pipes. All the participants unanimously felt this was too many solders for an assembly kit. The design problem in the pipe configuration was to eliminate the need for solder joints. As a result, I developed five different viable options using copper pipes (see Appendix 7 – plumbing). Four of the options follow the manifold principle while the fifth is a creative solution involving the bending of 1/2" soft copper pipe to create a serpentine configuration.

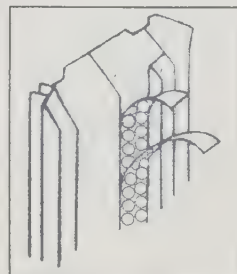


Figure 32: *Frame insulation*

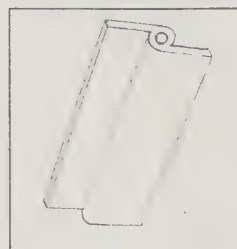


Figure 33: *An early concept design that combined absorber plate and plumbing pipe*



Figure 35: *Soldering joints — HETH workshop*

Arranging the pipes in this way would eliminate the possibility of internal leakage and reduce the panel maintenance. In addition, it would reduce the need for the co-extrusion, especially the pressure plate. One of my initial concerns with the serpentine pipes was flow rate, since there is less piping and it flows in one direction with no manifold. Another concern was the overall pipe diameter. According to plumbing experts, the serpentine design is reliable since it has been used in heating and cooling systems for decades. After taking all five options to Brainstorming I (see Appendix 5), consulting with several engineers at SESCO-NAC, and additional plumbers, I was satisfied to discover there are no significant losses with a serpentine system (see Appendix 7 –

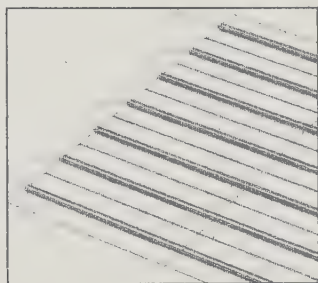
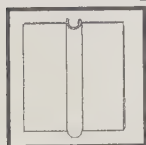


Figure 36: *Serpentine-styled plumbing pipe*

serpentine correspondence). It was agreed that the pipe needs to have at least a 1/2" inside diameter, but the larger the better. Additional design details require the serpentine to have smooth curves with a 6" diameter or a curve that is equal to the width of the absorber plate. After strongly considering the serpentine pipe system over the manifold system, I discovered several historical references of serpentine systems.¹¹ This piping system was phased-out

because of the production of pipes combined with absorber plate as in the *sunstrip* (see Figure 24) and the inability to easily manufacture a serpentine pipe. In order to use a serpentine pipe with a draindown system, the curves would be bent to 178° and be oriented with the bends on the vertical axis when mounted. This would allow liquid to evacuate the system when it is not in use. Presently, with computerized technologies, the serpentine pipe system is easily created and inexpensive (see Appendix 7 – plumbing cost comparison).

Absorber plates and surface coating



The absorber plate is the portion of the flat-plate collector that supports the absorber coating and transfers absorbed solar energy to the heat transfer fluid.

The absorber plate is the heart of a good solar collector. If the absorber does not function adequately, it affects the entire efficiency of the system.

After analyzing the Lee absorber plate, I discovered that it is an excellent design. It has been carefully engineered to collect the sun's energy on the fin and transfer heat to the copper pipe that is coupled with it. The absorber design has a crest in the center to keep it rigid when being manufactured as an extrusion. It is made with aluminum; therefore, it conducts the heat well and is compatible with copper both galvanically and with the

coefficient of expansion. The Lee absorber plate is unique from others available in the marketplace since it clamps onto the plumbing pipes. It is therefore designed for assembly and disassembly, which suits the sustainable model well. When I began this project, Tang Lee explained that the absorber plate was specifically engineered and considered to be superior by material and mechanical engineers. I am continuing to collaborate with engineer Bill Sellers about further refining the absorber plate design. Balancing the thermal transfer requirements and the design requirements for the extrusion process are critical details. It is possible that the absorber plate will be modified to suit other design considerations such as pipe dimension; however, the present design would be maintained with only small dimensional variations.

The absorber coating or paint needs to embody a variety of characteristics in order to prevent deterioration leading to unnecessary maintenance. Deterioration is defined as a result of loss of adhesion, change in composition, diffusion between coating layers, and changes in optical properties. Long-term stability is required with a resistance to high stagnation temperatures. All paints need to be thoroughly dry before installation. The coating requires the following characteristics:

- high elasticity due to expansion and contraction with high temperature fluctuations
- heat resistance of at least 212°F
- high resistance to corrosion (i.e., high humidity)
- application in a very thin layer
- ability to absorb the whole spectrum of light and emit weakly in infrared (i.e., increase solar absorption and decrease long-wave emission)

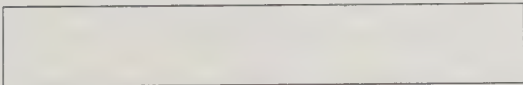


Figure 38: *Profile of the absorber plate*

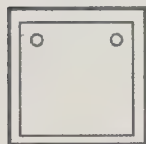


Figure 37: *Absorber plate on serpentine plumbing*

Selective-surface coatings are solar paints specially developed for this application. These are designed to provide the highest absorbance with the lowest emittance. After over a year of research, I was unable to find any manufacturer of such paints. In addition, most industrial paint manufacturers and distributors have no idea who might manufacture these paints. There are many companies referenced in publications; however, most are more than five years out-of-date. In the academic community, extensive research has been done on selective-surface coatings in Russia¹², but references are vague and there is no known manufacturer of these products.

Paint is significantly less expensive in larger quantities, but any paint product that can be applied by the home-owner, including aerosol paints, has negative environmental implications and all remnants of paints must be treated as chemical waste. The raw materials and by-products from paint application should be handled at a single location whenever possible. There are several paint application companies in Edmonton, such as *Doug's Place*, that run their businesses with the environment in mind.

Backpanel



A sheet material is required for the backpanel of the solar collector. When choosing the backpanel material, it is important to consider whether it can also provide cross-bracing, when the backpanel is fixed to the frame, in addition to containing the components within the frame. The backpanel does not undergo the same thermal cycling as the rest of the panel components since the backpanel has 1/2" of insulation separating it from the rest of the components.

A variety of materials were explored before deciding on recycled sheet aluminum (see Appendix 8). Because the backpanel relies on the extrusion design, I explored a variety of design options to contain the backpanel. One early concept was to use the same material for the backpanel that was being used for the glazing. This concept considered component re-use within the product. That is, the glazing would be interchangeable with the backpanel, creating a built-in repair option. But, after further consideration, I decided the additional weight and cost would be too prohibitive.

The Lee panel design required a fold which is only accomplished with a 'break' and is affixed with rivets. The use of rivets is necessary with the Lee extrusion since the backpanel is attached to the outside of the panel. The backpanel also acts to cross-brace the panel, which is an important feature since if it comes off or is loosened, the entire panel could be destroyed. The design solution was to bring the backpanel to the inside of the extrusion and attach it much in the same way the glazing would attach to the frame. By having the aluminum backpanel on the inside of the frame, the need for the fold is eliminated. This was a labor-intensive component of the Lee design. A proper fold can only be achieved with the specialized equipment, which is frequently used by ducting and house-siding manufacturers. Eliminating the need for a fold was beneficial to the overall design of the solar panel yet a method to affix the backpanel to the frame in order to provide structural integrity was essential. By lengthening one of the extrusion members and creating a mounting base (see Figure 31—number 5), the backpanel could be easily attached with self-tapping stainless steel screws. In addition to providing cross-bracing, the rivet was eliminated—reducing the total number of different materials and components needed for the overall solar panel design.

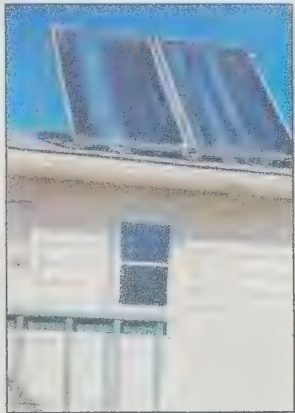


Figure 39: Wind damage to solar panels in the prairies

Seals and sealants



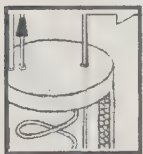
There are three different requirements for seals and sealants in the redesign of the flat-plate solar collector. The seals generally prevent heat loss and heat transfer. First, a silicone sealant is required for the mitered frame corners to help prevent heat loss. Silicone is also used to adhere the glazing and backpanel to the frame. Second, a glazing bead is required to hold the glazing and the backpanel in place and to create an air-tight fit between materials. This glazing bead acts as a co-extrusion with the frame but is manufactured from a synthetic rubber, EPDM. Third, a thermal break is required to prevent heat from transferring through the absorber plates, into the frame and out of the collector. Since the absorber plate and frame are both manufactured with aluminum, the heat transfer would be enormous (see Appendix 7 and 8).

Silicone is a commonly used material for bathroom and window renovations. This makes it an ideal material to use in the solar panel since most home-owners will be familiar with it as a product. Silicone is extremely durable and can be used in combination with a number of materials without losing its thermal properties. Silicone is emphasized in the assembly brochure—the amount used and drying time are critical.

The chosen glazing bead is manufactured by *Kawneer* of Lethbridge, Alberta—the extruder which is also recommended to extrude both the aluminum frame and absorber plate. In this way, one company manufactures three separate components in the flat-plate solar collector. This ensures a good fit between all components and supports the sustainable model. Unfortunately, EPDM is not compatible with all glazing options but it is an affordable and effective method to reducing the aluminum frame to a one-part unit. By using extruded components, there is no waste in the manufacturing process and nothing to recycle.

The suggested materials for the thermal break are high-temperature-rated synthetic rubbers, nitrile or neoprene. These come in a 1/16"-thick sheet which is ordinarily cut into desired pieces. If these pieces are curved in any way, there can be a high degree of waste in the cutting process. Therefore, the recommended shape for the thermal break are six squares, 1" x 1", that are not pre-punctured in the center

Heat transfer fluids



The transfer system is a major function of any solar collection system. Heat transfer fluids interact with other materials, which determines the need for future maintenance requirements. Many problems that occur in the solar collection system can be traced directly to the transfer fluid. Essentially, there are two classifications of heat transfer fluids: water and anti-freeze (see Appendix 8). Other transfer fluids that have been used include silicone, paraffinic oil, aromatic oil, and naphthenic oil. However, these are not as readily available. Liquid transfer fluids need to possess the following characteristics:

- high heat capacity
- low density or specific gravity
- high thermal conductivity
- low viscosity
- high boiling point and low freezing point

Heat transfer fluids, other than water, can be toxic even though the major constituents are relatively non-toxic. Used fluids have different toxin levels from those that are new. The dangers in heat transfer fluids relate to ingestion, contamination (in disposal or otherwise), and they can initiate fires. Most people dispose of fluids in sewers, septic tanks, and landfills, resulting in toxins leaching into groundwater, drinking water, open bodies of water, and food supplies.

If a glycol system is desired, it is recommended that a double-walled tank and exchanger be used so there is no possibility of contaminating the domestic water system. However, any type of anti-freeze or glycol mixture is not recommended for a domestic liquid solar heating system. The pumped glycol system requires a higher degree of maintenance on multiple levels.



Figure 40: *External heat exchanger at HETH*

Water is recommended as the heat transfer fluid because it possesses the desired characteristics and is non-toxic. The only limitation is that water has a low freezing point relative to glycol. There is ample documentation that indicates water to be the best transfer fluid since it is easy to handle and generally trouble-free. Edmonton water can potentially cause calcium and mineral deposits in the pipes, which could lead to additional maintenance requirements. As a result, it is recommended that distilled water be used in a closed-system (see Appendix 5 – Brainstorming II for detailed discussion on glycol/water debate).

The system hook-up



A solar collection system is comprised of three separate components:

1. the solar collector panel(s)
2. the transfer system which includes plumbing components (piping, isolation valves); insulation (for exterior and interior pipes); electrical pump, either an AC with differential thermostat and other measuring devices, *or* an electrical PV solar panel power source and a direct current (DC) circulating pump

3. the heat storage system which can be a second water tank with an external heat exchanger *or* a specialized insulated tank with an internal copper coil heat exchanger

There are a number of observed and documented problems that relate to the transfer of the medium between the collector and the storage components. The two major concerns in solar collection system design are: 1) freeze protection, and 2) allowance for thermal expansion and contraction. The weakest point in a water solar heating system is the liquid transfer component.

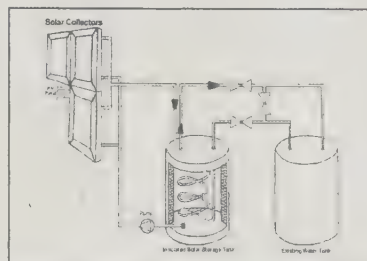


Figure 41: *The draindown system*

The simplicity of this system connection makes it easier for the owner to take responsibility for maintenance and repairs. The design considerations for developing a low maintenance solar collection system are itemized below.

There are a number of different systems connections that have been used in different situations (see Appendix 12). The system hook-up can be custom-created for each location and desired use; however, there are several systems that function poorly under the specific temperature variations in Alberta, and some that function better. The draindown system connection is generally recommended for retrofit and new design situations.

The draindown system is an indirect heat-transfer system that operates in a closed loop. The draindown system can typically use water or a glycol mixture. With this kind of system, a pump pushes the liquid through the pipes and into a heat transfer device. Typically, the pump works in combination with a differential thermostat, which prompts the pump to work only when the fluid is being heated. A power failure when using an electrical pump will cause 'draindown' because the system essentially shuts down. Typical problems in a solar connection system that relate to sensors include: 1) generally being inadequately protected from weather, 2) vulnerability to the high temperatures that are encouraged in solar collectors, 3) sensor coatings breaking down, and 4) sensors are often difficult to access for maintenance. Pumps rely on these sensors

to act when needed. In any solar collection system, the pump size must suit the system requirements (see instruction leaflet for mounting and system connection leaflet).

An off-the-grid system connection is recommended because it is self-sufficient and does not require the use of conventional electricity. A PV solar panel provides power for a DC pump (see Appendix 7 - pumps). The PV panel also acts as a controller. When there is more sun, it provides more energy to the pump thus creating more flow through the collector. This eliminates the need for sensors since at peak times of the day, the pump will be in use and at times when there is no sun, such as night time or overcast days, the system can essentially 'sleep' or 'draindown'. Accordingly, the piping is sloped in the flat-plate solar collector and needs to be sloped on route to the transfer tank. The serpentine form requires 2-5° to be subtracted from each turn, which makes the curves slightly greater than a perfect "U"-bend. This bend can easily be achieved by programming CNC equipment. This allows for ease of draindown. For full freeze protection, CSA standards¹³ state that all fluids from exterior pipes must be evacuated in less than three minutes. The CSA Handbook, *Installation Code for Solar Domestic Water Systems* would be included in the self-assembly kit. In the case of the redesign of the solar collector, it is estimated that complete evacuation occurs within less than two minutes. A 2-USGPM pump operates with 1 to 5 panels at 30 feet of head. This is the optimum distance needed between the storage tank and the solar panels, and is the recommended size for an AC or DC pump.

The thermosyphon system is recommended for the new design situations where it is feasible to place storage tanks in the upper story of a structure. Generally, an older building does not have the structural integrity necessary for putting a water storage tank in an attic or loft and the existing water tank would generally be in the basement. The thermosyphon system is less costly and easier to maintain because it does not need electrical components or a circulating pump. The thermosyphon system maintains a standard household pressure of 50 psi and works on the principle that heat rises. When the sun warms the water that is in the solar collector, it rises and circulation

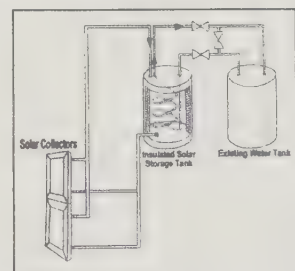


Figure 42: The thermosyphon system

begins. The hotter the water gets, the quicker it rises. The water flows through the collector outlet and into a holding tank that is mounted above the collectors. Cooler water falls to the bottom of the tank and into the collector creating a natural flow-through system. The water continues to flow as long as it is being heated and eventually stops entering the pipes when there is no longer adequate heat.

With all solar panel installations, they require breaking the building envelope. By doing so, the structure becomes vulnerable to ice dams, drainage problems, vapour barrier rupture, and leakage. The installation of the solar panels on a vertical wall eliminates the need to penetrate the roof, which is the most vulnerable location for leakage. Furthermore, the solar panel has been redesigned so that the pipes come out of the back of the flat-plate solar collector. This eliminates the need for plumbing pipes that would run outside of the house. Any piping that is exposed to the weather is vulnerable to degradation and freezing. Holes would be created in the outside wall of the structure, cut to accommodate the exact pipe diameter (1/2") exiting the panel. The pipes and holes would be siliconed to eliminate any possible heat leaks. Silicone is the best material for this job since it is inherently flexible and able to withstand the temperature variations of the entering liquid and the exiting liquid. This design is double-freeze-protected by using a draindown connection and by having all vulnerable pipes inside the structure or inside the flat-plate.

All the components that connect to the solar collector are vulnerable to expansion and contraction due to extreme temperature variations but not as extreme as those temperatures within the panel itself. These temperature variations cause movement and/or shifting of pipes and other components in the system connection and may cause leakage. Any flexible hoses that are used should be placed indoors, as they are extremely vulnerable to the elements—UV rays, rain, and snow. At present, there is only one known flexible pipe specific to solar on the market, available only in the UK.¹⁴ The solar panel(s) should be mounted exactly using the mounting flange to keep it fixed and stable in relation to the building. This will reduce the thermal movement and prevent pipes and hoses from disconnecting.

A danger with solar collectors is the high temperature of water in pipes and storage tanks. For safety purposes and to prevent heat-loss, hot-water return pipes and storage tanks need insulation. With a retrofit, the structure's existing water tank is used in combination with a storage tank. This allows for the water sensors and mixing valves in the existing tank to be used to keep water temperatures within a safe range. Other potential dangers related to the use of liquid heating solar collectors is flooding and fire. It is important that regular inspections and maintenance be done by the owner operating the solar collection system. A regular routine should include visual inspections every six months of the collector, transfer system, and storage tank. Possible pipe leaks or disconnected wires should be part of this inspection.

The redesign of the flat-plate solar collector began with a complex set of design criteria, principles of sustainable design, the analysis of a specific solar panel, and researching the history of solar collection. This project embodies many of the principles of sustainable design in addition to maintaining the strict functional requirements of materials, components, and the entire panel. It includes the cradle-to-cradle methodology where the individual components have been scripted by considering raw material extraction/refining, product life span, end-use, and re-use/recycle. The design of this panel also considers assembly and disassembly. Furthermore, the flat-plate solar collector would not work without a systems connection, necessitating exploration in this area as well. The final results are details on local manufacture options, recommendations for packaging with a take-back option, and a self-assembly kit. Finally, product durability and longevity has been addressed through material selection and by embedding meaning and additional value into the solar collector. The final result is a product design that may not necessarily appear different from its counterparts, but it represents the design thinking of a new generation of industrial designers.

¹ Baharam, S. "Product Symbolism of Gandhi and its Connection with Indian Mythology." *The Idea of Design*. (Massachusetts: MIT Press, [1998]).

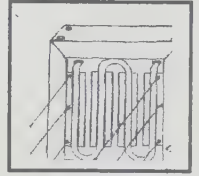
² Magee, Vishu. *Archetype Design—House as a Vehicle for Spirit*. (New Mexico: Archetype Design Publications, 1999).

³ Laurie Anderson in van Hinte, Ed. (ed.) *Eternally Yours—Visions on Product Endurance*. (Rotterdam: 010 Publishers, 1997) 19.

⁴ van Hinte, Ed. (ed.) *Eternally Yours—Visions on Product Endurance*. (Rotterdam: 010 Publishers, 1997) 26-27

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- ⁵ Whole Product Design Conference. Speaker Elizabeth Boncampe. *Product Endurance: Eternally Yours*. University of Washington. Industrial Design Division. (Seattle. Videocassette. October 1999).
- ⁶ Beattie, Donald A., ed. *History and Overview of Solar Heat Technologies*. (London: The MIT Press, 1997) 27-28.
- ⁷ Lesko, Jim. *Materials and Manufacturing Guide—Industrial Design*. (New York: John Wiley and Sons Inc., 1999) 109.
- ⁸ Homann, Peter and Chris Hilleary. *Solar Heating Materials Handbook—Environmental and Safety Considerations for Selection*. (New Mexico: Anachem Inc., 1981) 4.22.
- ⁹ *The Shapemakers Design Guide*. Wauconda, IL: Aluminum Extruders Council, 1988.
- ¹⁰ Beukers, Adriaan and Ed van Hinte. *Lightness*. (Netherlands Design Institute. 010 Publishers: Rotterdam, 2001)
- ¹¹ Butti, Ken and John Perlin. *A Golden Thread—2500 Years of Solar Architecture and Technology*. (Palo Alto, California: Cheshire Books, 1980) 135-154. and *Fundamentals of Solar Heating*. (Virginia: U.S. Department of Energy, January 1978) 3.6.
- ¹² Tarnizhevskii, B. V., G. A. Gukhman, A. I. Knyazeva, and M. I. Umarova. "Stable Selective Coatings for Solar Collectors". *Applied Solar Energy—Geliotekhnika*. Vol. 23, No.3. (New York: Allerton Press, 1987).
- ¹³ *Installation Code for Solar Domestic Hot Water Systems*. (Toronto: Canadian Standards Association, 1987) 23.
- ¹⁴ Grassie, T. and K. MacGregor. "Optimizing Flow controls in a Novel Solar Domestic Water Heating System". *NorthSun99: Proceedings of the Solar Energy Society of Canada's 25th International Symposium on Solar Energy*. Edmonton Alberta, August 1999. Gordon Howell et al. Canada.

Future recommendations



For the most part, solar products are perceived as futuristic technologies which alienate the average consumer. Common perceptions about solar product use are that they are fickle, expensive, require a high level of expertise, are unreliable and ugly, and/or take up too much space.

This problem has been compounded in the local area due to the number of failed solar collection systems. There are numerous domestic systems that have functioned well for many years. Unfortunately, these are not as visible as the failed industrial projects, such as the CN Rail railcar washing facility and Killam Recreation Centre. Solar in Western Canada is still considered an alternative. In addition, the public commonly confuses PV technologies with liquid- and air-heating solar technologies. Therefore, the need for more public information dissemination is critical. In order to educate the public, there needs to be 'new' supporters of solar technologies in society such as representatives from politics, economics, the social sciences, and the media. The collaboration demonstrated through this project illustrates the desire for solar engineers to work with other professions in order to create a solar revolution. At the *Solar Odyssey 2001*¹ conference, my paper was initially met with dismay and disbelief: "Where are your delta curves?" one participant yelled out from the audience at the end of my presentation. The solar engineers' language towards understanding solar includes efficiency, scientific data, proof, and 'delta curves' — all which demonstrate the heat gained from a solar collector. All solar heaters manufacturers in Canada and the US have standardized data sheets with delta curves as the central focus. Despite my seemingly negative impact on the crowd, my dinner table that evening was buzzing with questions and comments. The next day, at the round table open forum, Dr. Paul MacCready, from *Aerovironment*, designer of the *Helios* and other solar products, stated that my paper had been the most thought-provoking one at the conference. This opened the door for further discussion about the socio-cultural development of solar including solar use, and aesthetics. It was agreed upon later that day that there is a need

for more research in the areas I have been exploring and for more collaborative trans-disciplinary projects.

In addition to studying the socio-cultural aspects of solar, from the design perspective, there are a number of areas that could still be explored in the redesign of a flat-plate solar collector. In the sustainable design model, the design process is never complete—all objects/projects are design-in-progress. Future considerations involve further

“Search beyond the optimal ‘error-free result’ towards an ‘error-friendly solution’.”

Figure 43: Ezio Manzini, 1992

developing the relationship between the product and user. There have been a number of products designed that can provide technical feedback such as the *Solar Energy Technology Simulator* by *Omnidata Inc.* that first became available in 1977. Monitoring equipment can be easily linked up to home computers where they can provide minute-by-minute details on heat production. This type of equipment has been used in meteorology for decades and is now readily available. Gordon Howell of *Howell Mayhew Engineering* has such a system for his grid-connected PV panels. Primarily, the feedback device mirrors the high-tech approach to solar, providing data in mathematical language but not necessarily suitable to home-owners. I began to explore the idea of using heat-sensitive plastics for the connection system. These kinds of plastics are not presently being produced in North America. The potential for using heat-sensitive materials would provide better feedback to users just as a furnace blowing air cues the home-owner in knowing it is functioning. Simple visual cues will demonstrate to the

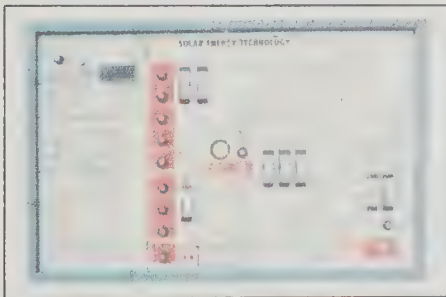


Figure 44: Obsolete monitoring equipment, Omnidata Incorporated.

user that the collector system is actually working.

This is a critical part to bringing solar energy to the marketplace since, according to several sources, it is not uncommon for owners of solar energy systems to be quite happy with systems whose solar components were not working and in some cases, had never worked.²

Additional design elements for future

consideration are to explore using the liquid solar heating panel without glazing or placing the panel inside the house, also without glazing. There has been some experimentation in this area.

by placing the glazing-free panel in front of a skylight or window. The benefit would be a worry-free user with no concerns of freeze-up since all the plumbing would be indoors. A considerable drawback would be the blocking of incoming sunlight. This design suggestion would be most viable integrated in a new design scenario rather than a retrofit of an older structure. Another area for exploration would be designing mirrors as reflectors into the system—which are presently being manufactured on liquid solar heaters in Japan. Another benefit may be in redesigning the overall panel shape to develop complimentary angles in a three-dimensional panel. However, there may be a three-dimensional configuration that is more efficient in terms of heat collection. Material design requires further exploration in the area of frame insulation. Perhaps a similar approach could be taken where a manufacturer could work with an insulation to develop a material specific to the solar collector.

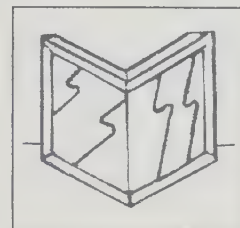


Figure 45: A three-dimensional panel concept for a vertical wall.

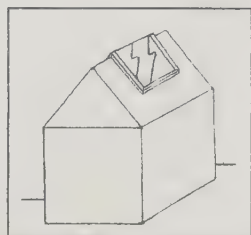


Figure 46: A three-dimensional panel concept for a rooftop.

The next stage before the manufacture of the flat-plate solar collector redesign is field monitoring and testing. Two different comparisons need to be done—first, between the serpentine and the manifold designs, and second, with glazing film to understand how much sunlight is being filtered out. I have contacted Dr. Doug Dale in Mechanical Engineering, University of Alberta, about beginning monitoring in January 2002. In addition, SESCI-NAC is interested in being involved in this process and has offered to provide support

where necessary. Following the data collection at the University of Alberta, I recommend the panels be sent to Alfred Brunger at the National Solar Testing Facility (NSTF) in Ontario. This data collection is essential in order to proceed with manufacturing and marketing the solar panel.

Upon completion, design details and material selection should be assessed for further durability and performance. In addition, the system connection should be detailed in layperson terms as have been the assembly instructions. This should be developed as a user's manual including potential operational problems.

The product manufacturer would be encouraged to establish a local support system of installation and maintenance specialists. I would encourage SESCI-NAC to take on this role in Alberta as they have the expertise, a good body of information, and an interest in environmental issues beyond solar. The manufacturer should also establish a take-back policy³ for packaging and the re-use or recycle of components/panels. Used solar components are at a premium for re-sale as there are so few products available on the market.

The supporters of solar technologies in society, the government, industry, academics, media, and the public, need to set realistic goals to build upon Canada's solar industry. For example, the goals of government could be to set policies and encourage the free-market forces to minimize the total long-term societal cost. These policies would help to prevent corporations and utility services from trying to 'meter' the sun and using the solar movement for self-profiting interest. In the US, utility companies have begun to market third-party energy services thus profiting from selling solar energy services and simultaneously distancing the public from solar technologies.⁴ Selling costly solar products such as PV as an electricity service means that the end user purchases the service, not a product. The cost of PV compared to the cost of fossil fuels makes it impossible for it to be used by individual home-owners. Furthermore, the sales of services from flat-plate solar collectors (heated air/liquid) are not as appealing to utility companies because 1) efficient air/liquid heating needs to be done on-site to minimize heat loss and 2) flat-plate solar collectors are cost-effective for individual home use. Therefore, it is feasible for flat-plate solar collectors to become part of a house, just as furnaces and hot water heaters are now. The key towards greater solar use globally is in recognizing the differences between solar products (PV and thermal) and the understandability and usability of them. The key to solar use in the province of Alberta is in the awareness of the limits to fossil fuel resources and in the environmental costs involved in using them. The potential for solar use in this province is enormous, shown by almost three decades of statistical data and growing public interest.

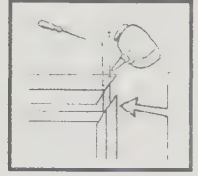
¹ *Sustainable Energy for Sustainable Communities*. Solar Odyssey 2001 – 27th Annual Conference of the Solar Energy Society of Canada Inc. (Regina, Saskatchewan. Sept. 28-30, 2001).

² Charles Bankston in Beattie, Donald A., ed. *History and Overview of Solar Heat Technologies*. (London: The MIT Press, 1997) 196.

³ Gertsakis, John, Nicola Morelli, and Chris Ryan. *An Introduction to Extended Producer Responsibility – Case studies showing how manufacturers are avoiding waste and recovering resources through product take-back*. (Australia: The National Centre for Design at RMIT University, 1998) 22.

⁴ Beattie, Donald A., ed. *History and Overview of Solar Heat Technologies*. (London: The MIT Press, 1997) 235

Conclusion



There has been and always will be an ongoing re-crafting of the relationships between the human race, designed material objects, and the environment. Sustainable design is a quest towards finding and achieving a balance between style, value, health, happiness, and safety at individual and social levels. By examining the social nature and purpose of design, there is increased understanding that design is multi-dimensional. That is, design has impact on social, psychological, spiritual, physical, and environmental levels. These are further layered with other factors such as technology, work tasks, and overall function, to name a few. All product development, such as the redesign of the flat-plate solar collector, has multi-factorial aspects but also embodies multi-dimensional characteristics. This design project explores sustainability as it relates to the practice of industrial design as well as beginning to develop a model for designers and design students to utilize.

The sustainable design model can be envisioned as a circle or wheel. The circle represents the universal law of motion: the cycle of life, death, and rebirth; concepts of continual change; and, fullness, relatedness, and interdependence. A sustainable design model recognizes a greater number of variables and considers participation of all components concerned. In considering more human-based issues, environmental issues naturally enter the picture. From a human point of view, a sustainable society is one that satisfies its needs without diminishing the prospects for future generations. Sustainability is the study of patterns, networks, balances, and cycles. Like ecology, the goal of sustainable design is to understand the functioning of whole living systems. It emphasizes durability and permanence, rather than ever-growing consumption. Design has slowly evolved into a more complex set of criteria for designers. This is due to the ecological understanding that design impacts nature and the environment.

Impact on the environment is created even with an act as simple as turning on a light switch. All human consumption involves ecological impact, which spreads out in complicated cause-and-effect chains. It is commonly known that fossil fuels will be depleted in the next

century—we have approximately 50 years' supply of oil, 65 years of natural gas, and 300 years of coal.¹ Even so, there is widespread agreement that humankind can markedly decrease its impact both in frequency and intensity, especially in industrialized parts of the world like North America. The world is currently in a globalization phase, with North American consumer patterns spreading everywhere—but this cannot last forever. Better technologies, like solar collectors, can help to reduce ecological damage and even generate profits in doing so.

The outside observer may view this design project with its seemingly endless lists of considerations as an example of obsessive/compulsive design behavior. However, this is the direction design is going—design is not as easy as it used to be. There is a need for a sustainable approach to design, which has implemented greater responsibility for individuals and communities. Countries such as Germany, the Netherlands, Sweden, and Britain have been engaging in this process for more than a decade. European and British manufacturers who make products successfully with sustainable considerations include, but are not limited to, Victorinox, BMW, and Philips electronics.

This project is an example of a small beginning to a quest for products that are more desirable, user-friendly, highly durable, toxin-free, created with carefully selected materials, and still maintain a high level of efficiency. Sustainable design searches for choices that present strong elements of reversibility in the physical, material sense. And in the immaterial sense, sustainable design searches for a tangible or intangible connection between product and people, therefore creating delight, pleasure, and longevity. By deepening relationships between humanity and objects through material selection and immaterial value, products can become part of a whole, reunited with the environment. In this way, sustainable designers are working to conserve culture and nature.

"In the case of design for sustainability, traditional gloom and doom environmentalist thinking has indeed given in to a strong belief in a make-able society."

Figure 47: Ed van Hinte, 1999.

¹ Graham, Ian. "Energy Forever?" *Solar Power*. (Texas: Raintree Steck-Vaughn Publishers, 1999) 4.

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Appendixes



- Appendix 1 — Professional activities
- Appendix 2 — Tangibles and intangibles of design
- Appendix 3 — Principles of sustainable design
- Appendix 4 — Life Cycle Cost analysis
- Appendix 5 — Brainstorming I and II summary
- Appendix 6 — Questionnaires results
- Appendix 7 — Component comparison
- Appendix 8 — Material selection
- Appendix 9 — Number of components and materials comparison
- Appendix 10 — Tools needed
- Appendix 11 — Extrusion profiles with dimensions
- Appendix 12 — System connection options
- Appendix 13 — Sustainable features

Available on request:

- Abstracts from presentations
- Brainstorming I and II agenda and notes
- Correspondence details
- Cost analysis for solar collectors (A-F) and system connections (X-Z)
- Extrusion manufacture and comparison
- Industry contacts and resources
- Professional meetings
- Questionnaire ethical review
- Questionnaire samples

Appendix 1: Professional Activities

Presentations

October 2001	<i>The Draindown Solar Collector System</i> Energy Awareness Week The University Eco-house, University of Alberta, Edmonton, AB
September 2001	<i>The Sustainable Redesign of a Thermal Solar Collector</i> National Solar Energy Society of Canada Regina, Saskatchewan
August 2001	<i>Solar Panel Building Workshop</i> Industrial Design, University of Alberta, Edmonton, AB
June 2001	<i>Brainstorming 2–Drainback, Draindown, and Thermosyphon Solar Collection Systems</i> Solar Energy Society of Canada Inc. - Northern Alberta Chapter, Edmonton, AB
June 2001	<i>Conservation, Sustainability, and Solar Heating</i> Keynote speaker for Green Communities McKernan Hall, Edmonton Alberta
May 2001	<i>(Im)materiality in the Design of a Flat-plate Solar Collector</i> Solar Energy Society of Canada Inc. - Northern Alberta Chapter, Edmonton, AB
May 2001	<i>Commercializing Solar Heating</i> Manasc Isaac Architects, Edmonton, AB
April 2001	<i>Solar Collectors and Systems Design</i> Edmonton Public School Board - Maintenance Division, Edmonton, AB
March 2001	<i>Brainstorming–Flat-plate Solar Collector Design</i> Solar Energy Society of Canada Inc. - Northern Alberta Chapter, Edmonton, AB
February 2001	<i>Sustainability in Practice: Designing a User-friendly Solar Collector</i> History of Design Seminar, University of Alberta, Edmonton, AB
November 2000	<i>Designing Sustainably: Material and Immaterial Design</i> The Society for Popular Culture/American Culture Association Albany, New York, USA
November 2000	<i>From Design-for-need to Sustainable Design</i> Art History 209, University of Alberta, Edmonton, AB
October 2000	<i>Solar Hot Water Heating</i> Energy Awareness Week The Human Ecology Theme House, University of Alberta, Edmonton, AB
October 2000	<i>The Human Ecology Theme House: Working Towards a Sustainable Design Model</i> Society for Human Ecology: Democracy and Sustainability Jackson Hole, Wyoming, USA
May 2000	<i>Toward A Sustainable Design Model: Transformation of a Residential Kitchen</i> ESAC 2000: Exploring the Shades of Environmentalism University of Alberta, Edmonton, AB
April 2000	<i>From Design-for-need to Sustainable Design</i> Art History 209, University of Alberta, Edmonton, AB

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May 2000	<i>Toward A Sustainable Design Model: Transformation of a Residential Kitchen</i> ESAC 2000: Exploring the Shades of Environmentalism University of Alberta, Edmonton, AB
April 2000	<i>From Design-for-need to Sustainable Design</i> Art History 209, University of Alberta, Edmonton, AB

Professional Presentations (continued)

January 2000 *EcoRedesign—Assessing and Developing Ecologically-sensitive Products*
Human Ecology, University of Alberta, Edmonton, AB

Conferences and Workshops Attended

September 2001 *Solar Odyssey 2001*
The Solar Energy Society of Canada Inc.
Regina, SK

September 2001 *Solar Failure of Hot Water Heating Systems*
Alberta and Saskatchewan

June 2001 *Eco-design for Competitive Advantage*
Institute of Mechanical Engineers, London, England
The Surrey Institute of Art and Design
Centre for Sustainable Design

May 2001 *Evacuated-tube Solar Heater Removal and Salvage*
Calder CN Rail Yard
Edmonton, AB

April 2001 *The Sustainable Building Symposium*
Royal Glenora Club
Edmonton, AB

February 2001 *Solar House Tour*
Solar Energy Society of Canada Inc. - Northern Alberta Chapter
Edmonton and area, AB

November 2000 *The Society for Popular Culture/American Culture Association*
Albany, NY, USA

October 2000 *Society for Human Ecology: Democracy and Sustainability*
Jackson Hole, WY, USA

July 2000 *Solar Panel-building Workshop*
Hosted by the University of Calgary, the University of Alberta, and the Solar Energy
Society of Canada Inc. - Northern Alberta Chapter
University of Alberta, Edmonton, AB

July 2000 *ESAC 2000: Exploring the Shades of Environmentalism*
University of Alberta, Edmonton, AB

April 2000 *Better Housing Conference 2000*
Continuing Education, Edmonton Public Schools
Edmonton, AB

February 2000 *Towards a Sustainable Future*
Solar Energy Society of Canada Inc. - Northern Alberta Chapter
Edmonton, AB

October 1999 *Whole Product Sustainable Design Conference*
University of Washington, Seattle, WA, USA

Conferences and Workshops Attended (continued)

September 1999 *Making Connections: Design and the Social Sciences*
University of Alberta, Edmonton, AB

Exhibitions, Publications, and Media Exposure

April 2003 *Upcoming exhibit — Comfort Zone*
McMullen Gallery, University of Alberta Hospital, Edmonton, AB

April 2002 *Upcoming exhibit — Room Material*
Profiles Public Art Gallery, St. Albert, AB

November 2001 *Commentary on Karim Rashid, Sustainability and Postmodernism*
Definitely Not the Opera, CBC Radio, Winnipeg, MB

September 2001 *The Sustainable Redesign of a Flat-plate Solar Collector*
Solar Odyssey 2001
Solar Energy Society of Canada Inc. - Annual Publication
Ottawa, ON

November 2000 *Speculations Group Exhibition*
Alberta Craft Council, Edmonton, AB

July 2000 *Making an Environmentally-friendly House a Home*
University of Alberta Online Express News

March 2000 *Old Building Lives on in Sustainable Design*
Edmonton Journal

Professional Affiliations

2000-2001 *Solar Energy Society of Canada Inc.*
Member

2000-2001 *Solar Energy Society of Canada - Northern Alberta Chapter*
Member

2000-2001 *The Society for Popular Culture*
Member

2000-2001 *Society for Human Ecology*
Member

2000-2001 *Environmental Studies Association of Canada*
Member

1989-2001 *Harcourt House Arts Centre, Edmonton, AB*
Member

1994-2001 *Alberta Craft Council, Edmonton, AB*
Member

1996-2001 *Profiles Gallery, St. Albert, AB*
Member

1996-2001 *Latitude 53 Gallery, Edmonton, AB*
Member

Appendix 2: Tangibles and Intangibles of Design

Tangibles

The tangibles of design are those definable items which must occur before an object can be made.

- Materials :: Materials are what an object is made from and include both natural and man-made.
- Production :: Production refers to how an object is constructed or made and what processes go into its creation.
- Designer :: The designer or creator is who develops the idea of the object and is sometimes the individual who makes the object.
- Audience :: The audience or user id for whom the object is made.

Intangibles

The intangibles of design are those items which are less easy to define but which occur, to varying degrees, in the creation of objects.

- Cultural Context :: The cultural context is a society's ideas and values represented politically, economically, socially and artistically.
- Impact :: Impact is the direct or indirect effect an object has on an individual and / or group of individuals.
- Symbolism :: Symbolism is the meaning that is attached to an object in an obvious or subtle manner so that the object's purpose is greater than its function.
- Philosophy :: A philosophy refers to the belief systems of a society or societies and the personal beliefs of the designer which effect the making of objects. Does the object challenge or maintain the status quo?
- Value :: The personal or financial worth of an object to society or individuals.
- Suitability and Evaluation :: The success or failure of the idea of an object compared to its final form and use. What was the object intended to do? Does it do it? How well does it do it?

Appendix 3: Principles of Sustainable Design

The principles of sustainable design

Sustainable design is based on ecological principles of connectedness and holism. Therefore a cradle-to-cradle approach is required. Cradle-to-cradle is the notion that products are designed as part of a successive cycle or circle. The circle is ideally closed within a cycle and includes a greater number of variables than the linear production-consumption chain. There is greater attention to care and participation of all parts that make up the whole, and of how those parts relate to the whole.

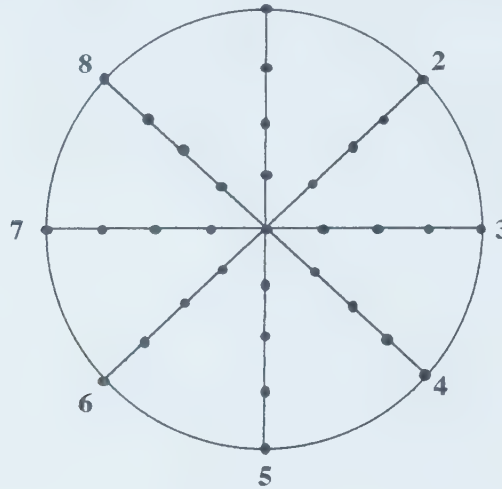
These variables attempt to be all-inclusive with concepts including the following:

- ☐ designed with locally available materials
- ☐ designed with recycled content
- ☐ minimized lifecycle energy
- ☐ minimized material-use
- ☐ renewable material-use including energy materials and processes
- ☐ avoidance of environmentally harmful materials and processes
- ☐ designed with reusable local resources
- ☐ designed for durability
- ☐ designed for disassembly
- ☐ designed for longevity
- ☐ designed for easy maintenance
- ☐ designed for easy repair
- ☐ designed for easy upgrading
- ☐ designed for recyclability
- ☐ reuse of product components
- ☐ designed for people
- ☐ designed to be cost effective

Appendix 4: Life Cycle Cost Analysis

Life Cycle Design Strategies – LiDs wheel*

The stages of the product's life are estimated with degrees of impact plotted on the radial axis. This produces the estimated "ecological footprint" for each product. The centre dot represents the least negative impact on the environment.



1	Design for innovation and change • satisfy the need through service provision • rethink how to provide the function • meet and exceed the intended need • anticipate change and build in flexibility	5	Design for efficient distribution • reduce product and packaging weight • use reusable or recyclable packaging • use an efficient transport system • use regional production and assembly
2	Design for low-impact materials • avoid toxic or hazardous substances • avoid ozone-depleting substances • avoid the production of greenhouse gas • use materials with low embodied energy	6	Design for low-impact use • eliminate pollution emissions • eliminate energy inefficiencies • eliminate water/material use inefficiencies • incorporate multi-condition/range efficiencies
3	Design for resource conservation • use minimal materials • use renewable resources • use materials which do not deplete natural resources • use recycled and recyclable materials • use waste by-products	7	Design for optimized lifetime • build in user stewardship • build in producer stewardship • build in durability • build in maintenance repair capabilities • build in ability to upgrade
4	Design for optimized production • implement continuous improvement • implement quality control • implement waste reduction methods • reduce energy and waste consumption • segregate material types for reuse/recycle	8	Design for optimized end-of-life • provide for disassembly • provide for reuse and recycling • provide for remanufacturing • provide ability to degrade • provide for safe disposal

* Based on the LCA used in Gertsakis, John, Helen Lewis and Chris Ryan. *A Guide to EcoReDesign™: Improving the environmental performance of manufactured products*. Centre for Design at RMIT. Australia. 1997.

Appendix 5: Brainstorming Sessions 1 & 2 summary

Brainstorm Session 1: March 3, 2001, The University of Alberta

In attendance: Megan Strickfaden, Leanne Kisilevich, Brian Johnston, Simon Knight, Dan Langford, Dick D'Alquen, Richard Ruman and Robert Lederer

Topics discussed

Extrusion

- 41% of the cost savings would happen with the elimination of the pressure plate which consists of quite a bit of additional aluminum. Quite a bit more aluminum is used in that pressure plate
- it's costed out based on minimum costs for extrusions and minimum weights and over a period of time the savings would be greater because significantly less material is used in the design

Q: Would it be mounted on a sloped roof?

- it would be mounted upright as it gives more collection in this climate and it would be mounted on a wall or on a balcony quite high so you get greater reflection off the snow and solar collection for greater parts of the year
- the weight is definitely a factor here

Issue: Accessing the inside of the panel to clean the glass, difficulty of installing the glass

- the type of glazing system used in this panel is no different than what's used in outdoor signage. The idea is to build the panel so that you can have easy access on one side of it, to be able to slide the glass in and out. Taking only one side off is more efficient than taking the whole front face off and then having to take a side piece off.
- a combination area for screws and glue/gum hold in the glass
- inexpensive, corner u-shaped bracketing is also used in outdoor signs — around the glazing areas and which give guidance when you're inserting the glass. The brackets also help keep it square. They keep the glass held rigid.
- size is an issue, you wouldn't want an extrusion 4' x 8'. And, depending on where it's mounted, you can do have the opening at the bottom so that the glass slides out easily.
- accessing it isn't a big issue when you only have to open it perhaps once a year for maintenance

Issue: In Tang Lee's panel, double-glaze glass is used, but can you use it in this one without having to change the design? In this climate, you may want double-glazed glass.

- might be easier to have two sets of extrusions made — one for northern climates and another for southern climates
- this new extrusion can accommodate up to 4 mm which is almost 1/4". If the double-glazing glass were used, the extrusion could be made slightly wider, use different weather stripping and adjusted accordingly. The modification to accommodate thicker glass would perhaps add about 5% increase in material used and allowance would be needed for an extra 1/4"

Frame

Issue: It's not an easy job removing the glass if the whole unit is unstable/wobbly

- there is a mounting flange and you could drill through and mount the frame on three sides so that it would be firmly mounted. Your wall becomes your cross-brace when you mount it on two sides

Q: Is there any consideration for this being mounted at an angle?

- it's possible, a bracketing system could be created for mounting it or,
- the "guts" inside the panel could be angled

Issue: solar access - getting enough rays - angle of panel and the necessity of it being on the roof

- particularly in urban environments, you need to put it on a roof as opposed to the side of a house, or else have a hard time getting enough energy with them, especially in the winter
- you definitely want to mount it vertically in winter
- R. D'Alquen advocated that still there is an advantage of the upright positioning to maximize energy absorption

Issue: Use of materials to make the frame

- found no extruders who will use recycled aluminum or even low-quality aluminum
- aluminum efficiently absorbs a lot of heat. Steel does too, but it rusts
- while aluminum captures heat very well there's still also a lot of heat loss and insulation would have to be used inside the frame to prevent that heat loss
- none of the plastic products researched would withstand the high temperatures

Issue: Other materials to use for the frame?

- wood – but it requires maintenance
- PVC can't handle the thermal shifts

Metal back plate

- galvanized steel is a poor material to use for it. Using aluminum would improve it but again you need more tools to assemble it so the thought was to eliminate the metal back panel altogether
- the intention was to create this as a self-assembly kit but with the metal back plate, it means you require a rivet gun and a break, which is a huge piece of equipment
- an alternative is to get the fold done elsewhere but this can vary from the inexpensive to very expensive depending on where you get it done. It also may not be perfectly square, depending on who does it and how well it's done
- the issue is you want to keep the back area as well sealed as possible from dust and moisture
- the new design of this panel was purposely made with a multi-functional ability so that it could heat air as well as water. For air heating, the back panel accommodates an air duct and the plumbing just wouldn't be put in
- B. Johnston suggested making a system where you could inter-switch between heating water and air. The idea would be to use the system heating water during the warmer months and then drain out the water just before temperatures started to get close to freezing and then heat air over colder months
- the new design accommodates an absorber plate

Glazing

- a) tempered glass potentially has the longest life but its weight is a huge factor
- b) Lexan products – can withstand temperatures and has UV protection – one study recommends Lexan over glass
- c) Verilite, which Tang used, (Lexan Thermoclear used for greenhouses) has a lower temperature threshold but is still a possibility

Issue: any water in the system and the glass both definitely add weight. Was there any consideration about plastics and whether they can ‘take’ the temperature range?

- Richard Ruman mentioned a plastic sheet-piece used for a solar cooker. He couldn’t recall the name but perhaps it was Tetlier(?) and was possibly a 3M product, very expensive but meant to tolerate high temperatures better than tempered glass. The solar cooker gets up to 350°F so the sheet piece could withstand the heat extremely well.
- with UV-film protection, it scuffs over time and this could affect the plate finish and its ability to absorb the light (like a scratched glass that’s harder to see through)
- issues of reflectiveness and efficiency were also questioned

Plumbing

Options:

- 1) manifold top/bottom grid
- 2) compression tees – very expensive and heavy
- 3) pex? temperature tolerance low
- 4) soft K-type copper used

- the design solution would mean changing the design of the absorber plate. Ideally, if there was to be a manifold, and something snaps into it, we might as well eliminate the copper and turn it into one extrusion
- the issue with aluminum is that it softens and wears out faster
- a one-piece unit consisting of an aluminum piping with copper lining in the middle to reduce the wear on the absorber plates was considered a very good option
- there were no plastic components researched that could withstand the temperatures
- discussed issues of efficiency of water flow pumping through the piping system and how that might affect heat loss, water flow, flow pressure. Also discussed how heat transfer would be affected by various parts, absorber plate size and the overall design. There are thermodynamic issues to be examined yet – the best orientation of the piping, draining of the piping, efficiency of heat absorption, water flow, etc.
- copper piping is the norm and it would probably be best to stay with the standard types of plumbing piping. It’s less expensive. What also needs examination is what is being lost in heat transfer/efficiency in the area where the piping is. This is assuming, too, that the same absorber plate is used that was in Tang’s original design. These things need to be looked at.
- a suggestion was made of running two parallel piping tubings within the panel
- S. Knight suggested that instead of having all this copper piping bending all over, instead, putting in a plastic sheet, with a tube at either end of it, and running water down /through? it. The sheet might be aluminum and/or have sort of a honeycomb design. The only problem may be if water flow fails, then the sheet’s ‘toast’.

Q: Is there a more inert aluminum available on the market?

- wasn't able to find out about any at this point

Insulation

- foil-face insulation is available and different variations on the foils, which though, are only rated up to 190°F although foil faces are typically only rated up to 200°F
- could consider something more rigid and not a composite which would probably be better so that the components could be recycled easily
- if we know that the fibreglass was recycled that would also be better
- the foil-face insulation is being phased out now and loses its r-rating once it gets moist or condensation builds up on it
- Can-Cell makes a loose-fill insulation, although not exactly what is needed but it could be put into a bag, fluffed up and slid into the panel. It's recycled product so it could be removed from the panel and recycled. Its continuous temperature rating is 190°F. Can-Cell said they'd be happy to make a product asked for – something they can use in combination with their weather shield product. It's lucrative as they're a local company. They would be asked if they could make some foil envelopes in which to put the insulation.
- R. Ruman suggested glass mats used in industrial settings – mats that can be grooved and could withstand those kinds of temperatures. It would be a board, but the weight would be heavier. However, it's rigid and perhaps various size widths could be made. It can take those kind of temperatures without out-gassing. R. Ruman suggested talking to insulator companies and finding out about newer products coming out on the market.
- a foil insulation product would be better without any plastic component as the plastic limits its temperature tolerance

Marketing

- S. Knight brought up the issue that this product has potential but you still don't know whether it is marketable. Can anybody afford to buy it? Can you market this as a product that consumers would want to buy instead of standard hot-water tank? Questions consumers might ask: "how much energy is this going to save me in the long run? What's the payback? How long would that take? The bottom line is always money, the "economic myth". If you can't crunch the numbers and prove it to me, then I may not be so convinced. You have to consider these implications and how to make it marketable. S Knight suggested contacting the MBA dept. in the U of A Business faculty – ask if their students would consider doing this as a project? "I've got a product, is it marketable?" Have the MBA do the research on it for you. You have a great idea, a concept, but you need to write up a business plan/case to help clearly state your business case. This business plan would be very useful even to use for selling the product to other countries, like China, for example, where there'd be big potential for use of these.
- S.Knight would like to see a business case put together. This would help convince consumers/companies more that you've done your research, your calculations on energy-savings, etc. and make it lucrative as to why you'd purchase this system

Brainstorming Session 2: Solar Domestic Hot Water Heating Panels June 9, 2001, The University of Alberta

In attendance: Megan Strickfaden, Leanne Kisilevich, Brian Johnston, Simon Knight, Richard Ruman, Michael Sawyer, Paul Reich, Albert Aris, Ed Bushy, John Hughes, Norm Larsen, and Daryl Colyer

Topics Discussed

Issue: For the panel system, there are different heat transfer and heat storage systems to choose from — which would be best?

- they can be simple or complicated, but if more components are involved, obviously with a more complex the system, more parts could fail. CN's solar-heated hot water system for ten railcar washbay stations was one example given of those kinds of system problems. The system was installed in the mid '80s costing about \$2 million, but the system worked for only about six months.

Issue: Tilt angle for the mounted solar panel

- R. Ruman asked whether the optimum angle for mounting solar panels was 45° at this latitude. B. Johnston gave a rundown of angles presented in an Alberta Research Council study that said depending on the time of year, there are different optimum angles. M. Strickfaden said that what this long-term study (10 years) also showed was that the tilt angle was not crucial. She said that Tang Lee recommended that the panels be mounted at 90°, as they are on HETH. Panels at this angle, particularly in winter, would allow for the best reflection of light from the snow cover.
- J. Hughes asked about the idea of having a tracker to assess the effectiveness of the tilt angle. Would the cost of a tracker be offset by the energy savings? M. Strickfaden said that trackers are very expensive and there would be more moving parts to contend with. She emphasized that it's more important that the panel be on a south-facing side than changing the tilt angle of the panel.
- P. Reich asked if the roof was not the best place to put the solar collector panel since it receives the most sun. It was pointed out to him that one wants to make use of the collector the most during winter months and that the south side of the house does get plenty of sun as well as light reflection from the snow cover.

Issue: Flexible pipe connectors

M. Strickfaden said this is a major issue. Would need connectors that could be insulated *and* flexible. The suggestion was made about using silicone hoses.

Issue: Mineral buildup clogging up pipes

There was discussion about how using water in the collector system creates the potential problem of calcium/mineral deposits in the pipes. E. Bushy said that rainwater, soft water, hard water, and acid water all contribute to the problem in different ways, even with their different compositions. Unless you treat the water and reuse it in the system, he said, there is still a problem of calcium deposits. He also said that using distilled water in a closed system would be the most ideal and there wouldn't be the problem of scaling build-up.

B. Johnston asked if de-ionized water would work using a low-voltage system to de-ionize the water. E. Bushy said the level of water hardness would have to be below 5 parts per million. 15 parts/million is really high.

Issue: How feasible would a glycol-based collector system be?

There was discussion about glycol not being as good as using water because glycol breaks down materials, and needs to be changed relatively frequently. And if you don't have mixture right, you have to worry about freeze-up, and/or degrading materials in the collector. M. Strickfaden said that even though it's supposedly non-toxic, there are still potential problems of it being used, even in a closed loop. Solar failure research has shown that glycol has caused corrosion to heat exchangers

and there's risk of it contaminating potable water. If there is stagnation in the system, glycolic and oxalic acids form and these attack metal pipes of all kinds – steel, aluminum, and copper. They also break down any plastic or rubber products.

Issue: Is a water draindown system the best?

The example of Dick D'Alquin's solar collector system that has a closed water loop was given. B. Johnston said the system is 15 years old and there have been no problems with it. It works effectively with the temperature sensors in it. There are two solar collectors on the roof and two storage tanks in the basement. One transfer tank is plastic insulated. The water is in its own line and it passes through the heat storage tank and picks up the heat and transmits it for heating.

The importance of proper installation of the draindown system was stressed; if it's designed well, something like that can last forever by doing it right in the first place. B. Johnston said CN's project has drain pipes that "looked like spaghetti" due to the failing mounting anchors. He also alluded this being one of the problems with the system.

Installation/System Issues

heat exchanger

The efficiency of the heat exchanger was discussed – there is a range from the homemade to commercially available ones for about \$3000 ones. M. Strickfaden said that if a glycol system was used, you would need a double-walled tank – but you lose efficiency with the double-wall. With a water system, you can have a single-wall tank and with no risk of contamination or other problems associated with glycol.

heat storage tank

N. Larsen asked about having a big enough heat storage tank and issues of making the best use of that heat, if it's being gathered during the day, but sitting unused until mornings and evenings when it's primarily used for bathing, and washing dishes, etc. He asked, what do you do with all the hot water heated during the day? How do you make use of it to the best extent? There was more discussion about having to consider the energy considerations of an existing house and how it's affected, as opposed to an newly-built, more energy-efficient home. M. Strickfaden said that there are already recommended sizes of storage tanks for different-sized solar collector systems.

To some extent, people would have to modify their lifestyle habits working with changes in heated water. S. Knight said many people wouldn't want to modify their lifestyle in having this system. They'd want a system that was relatively simple, wouldn't require a lifestyle change, and was cost-efficient.

P. Reich suggested what about the idea of having a radiator-style heating for a house, using glycol in a closed loop so that no storage would be needed.

The thermosiphon system is the only one that doesn't require pumps. Still, the question was, how do we get heat from the roof to the storage tank below.

Then there was the question of water stagnation. Is there a risk of bacterial/algae growth in the system? J. Hughes said that as long as water is kept moving through the pipe system, bacterial growth won't happen.

Q: Water or glycol solar collector system?

- The consensus was for using water in a drainback system. It would eliminate having to contend with glycol and any associated problems with it. A drainback system runs well since when the pump shuts off, the water drains back down.
- B. Johnston said that in the water system, as part of a separate loop, some of its coil could be going through the furnace, drawing the heat. It would be similar to an air conditioning unit attached to the furnace. In the heating case, the water would be used for house heating and for heating the hot water. One potential problem might be that the water in the coil might cool too much, as it came out of the furnace, thus losing heat and energy efficiency, before getting to the storage tank.

- M. Strickfaden suggested that if you have a PV driven pump there would be no need for thermostats.

Issue: In a retrofit situation, how would we effectively connect the plumbing of the solar from the outside of the house to the inside?

- How could this be done without creating a complex system? It was agreed that it would be less complicated and more energy efficient to have it go directly into the tank rather than to an auxiliary tank.
- S. Knight commented that the average homeowner wouldn't be doing the installation themselves and suggested having instructions included for the contractor. He stressed that the instructions should be very specific and clear by highlighting important instructions in a box. He said make sure reasons are given as to why it's necessary that things be done in the order that are indicated. Otherwise, contractors have the tendency to fall back on 'what they know' and install things using their own methods which could potentially foul up the solar collector's effectiveness.
- J. Hughes suggested that the instructions perhaps include specifications for examples of how to install the system through a masonry wall or a wood-frame wall.
- Considering that cutting into the roof could create many potential problems, it was agreed that rigging the plumbing right through the wall (directly in behind the solar collector mounted on the side of the house) and into the home would be the best. J. Hughes said it was important the installation be done well so that there wouldn't be problems in this area when it was 'sealed up'.

Issue: Are there ways that would allow the owner to interact better with the solar panel?

- S. Knight commented that most people wouldn't care about interacting with the panel – that all they wanted to know was they could put it together and make sure that it works. A. Aris gave the example of when he was trying to explain to a friend the concept of refrigeration but she wasn't interested in hearing about it; she was just wanted it to work. Others commented that it's the same with furnaces – people just want them to work. M. Strickfaden stressed that it was exactly that kind of interaction barrier she was trying to overcome by designing her kit to be "user-friendly". It's not about selling it, but about creating something of more value to more people. and if they find this product works for them, they'll look for other products that embody those same qualities and/or sustainable principles. It's about establishing the added value of creating a product that people can 'interface' with.
- She stressed that one of the primary reasons that she was re-designing the solar collector in the first place was to enable the layperson to actually "interact" with the panel and not just leave that relationship of knowledge between the product "and the engineers [who designed it]". The intention of making it into a kit was to allow the layperson to build it themselves, learning how it worked, and being capable of doing the maintenance on it by themselves.
- Others commented that certainly, given the choice, consumers will make a better choice for a product that considers the environment, because they 'want to do the right thing'.

S. Knight and others suggested adding a visual feature to the panel, to draw the person's interest to it, since it works quietly with no obvious signs. Such a feature could be a heat calibrator, meter or gauge or part of a pipe with a color changing heat sensor showing the temperature changes happening. This would help create a better 'connection' between the user and the product.

Appendix 6: Questionnaire Results

(Summary of 16 responses)

General Survey Results

Part one – Environmentalism and sustainable design

1. **Do you consider yourself an environmentalist? Why or why not?**
 - yes, however, this is tempered with a large dose of reality.
 - I love the outdoors, green space and wilderness.
 - Yes, because I am constantly aware of effects on the environment when going about daily tasks and errands and go to some inconvenience and expense to lessen my own damage to the environment.
 - No, there a lot more I could be doing myself.
 - I consider myself environmentally aware but not an environmentalist. I still drive a car, though I use a bus daily, I think still of convenience before efficiency, and I only react to issues instead of thinking ahead and moving to make changes.
 - Yes, always looking for ways to improve on how my family and I affect the environment.
 - yes, because I make decisions with environmental concerns in mind
 - yes, I actively teach and encourage young people to consider “saving” the environment in all of their actions, and to consider themselves as part of a whole ecosystem
 - yes
 - yes, I limit my consumption to essentials that sustain life; I purchase products which are green; I compost and purchase recycled building products and clothing
 - yes, because stewardship of creation is critical to the health of our community
 - yes, to some extent. I am concerned about how the environment is being affected by human activity, i.e., garbage, car pollution, resource use/abuse/overuse, impact of pesticides/herbicides
2. **Do you consider yourself a:**
 - pale-green consumer
 - medium-green consumer – 10 responses
 - dark-green consumer – 1 response
 - never heard of the terms – 5 responses
3. **Would you consider your knowledge base in sustainable issues to be:**
 - excellent – 1 response
 - good – 6 responses
 - fair - 7 responses – (one added this comment next to it:) but sometimes I surprise myself
 - poor – 1 response
4. **What do you know of sustainable design?**
 - Potentially the answer to our technical problems but not all of our social issues.
 - I think that it relates to the amount of energy it takes to make a product, as well as its durability and recyclability.
 - What I understand by the phrase is design which does not require depletion of finite resources. It is therefore an ideal that designers must be guided by in order to pass on to later generations as many options as we have today (or more) and an undiminished environment.
 - Little – 2 responses
 - Low impact, something that is long-term, efficient, and maintainable?
 - Not very much.
 - I know very little about actual sustainable design that is readily (i.e., in The Bay dept. store) available to the consumer
 - embodies environmentally-friendly, energy-efficient and healthy housing aspects; implies a balance of what is taken from the planet in terms of what can be regenerated
 - my design (interior) uses tile and fast-growing wood for floors – carpeting is not a good

choice although it can be cheaper at first – it is toxic and harbours dust mites. No wallpaper!

- I'm just learning now

- my understanding is that it is design of products made with materials that don't "hurt" the environment – that the production of the products also doesn't impact the environment and when the product is no longer usable, its component parts can be recycled and reused
- only rough concepts of it

5. **Do you know the difference between a product that promotes sustainable living and one that has been designed with sustainability in mind?**

- Yes.

- A product that promotes sustainability in my mind would be a bicycle. The bicycle may not be designed with sustainability in mind.

- Frankly, no. However, on reflection, I could theorize that a product that really does promote sustainable living has achieved the ideal, whereas a product that has been designed with sustainability in mind does not necessarily achieve the ideal.

- One cannot function without outside supplied energy. One that is self-sustainable.

- I believe the difference to be a "sustainable living"-promoting product is one which encourages or endeavors the consumer to have a lifestyle which is self-supporting whereas a product designed for sustainability lasts a long time and its by-products and worn-out parts can be used again.

- No – 5 responses

- recycling; the electric solar panel flashlights are designed to provide sustainable light

- one that promotes sustainable living I would think would mean one that improves the long-length or usability for living – one designed with sustainability in mind I would think means a product that is always sustainably designed in its whole cycle of "life" – all its components/materials/use accounted for

- not really

6. **Can you name any industrially-produced products that you feel embody principles of sustainability?**

- chairs with McDonough fabric

- Possibly newspapers, if the newspapers are recycled into "new" newspapers, or recycled into insulation.

- P.V. solar panels, low-flow shower heads, geo-thermal hardware, wind turbines, DHW solar collectors, organic farm product, etc. – but there may well be unsustainable elements in the manufacturing history of these products.

- solar panels, bicycles, – maybe not; forest products are what come to mind, because they are harvested and replanted for future needs.

- a carpet company in the US which takes back its old carpets to remake them into new

- cork flooring; bamboo furniture (maybe)

- solar panels

- No.

- carpets by Interface corp.; carpets made of pop bottles; cellulose insulation

- asphalt material made from old car tires; plastic recycled into boards used for picnic tables

7. **Do you prefer or endorse products that are locally designed and manufactured? Why or why not?**

- Yes, depending on cost differential.

- Yes. Local design for products that have to face local climatic conditions. Local manufacture to avoid excessive transportation. Local employment is also a benefit.

- Yes – 1 response

- Yes – I feel the answer is self-explanatory!

- Yes. I believe in supporting the local economy and minimizing transportation costs.

- Locally puts money into your area. Close to same cost I would buy local.

- Yes. My bike was manufactured locally and I support the manufacturer because the product was /is reasonably priced, well made, and can be maintained locally. There is a support infrastructure I can approach locally.
- Yes, keeps and provides jobs in the local area.
- local economic support is very important (small is beautiful)
- yes, because they promote jobs for local people, reduce shipping, and often also reduce packaging
- sometimes, but cost is also an issue
- yes, farmers' market products are locally designed – sometimes a local product is great but comes at a much higher price than one produced in Mexico
- best price for the best product is the bottom line for me
- yes, because it helps our community have a sense of purpose in life
- locally-designed products would be a bonus although whether they'd be cheaper than something made overseas is questionable. I wish more was made locally and/or in Canada. Quality is sadly lacking these days.

8. Are you interested in having more information about the origins of materials that go into products that you purchase (i.e., place they are made, how they are made)?

- Yes – 9 responses
- Yes, not just material but embodied energy.
- Yes. In general, there is very little information on how and where something is made. It would also be interesting to know how much energy it took to make it.
- Yes. This would help me make environmentally appropriate choices and would make manufacturers aware of the issues.
- Yes, more information better the final decision.
- yes, it would help the consumer to make more environmentally supportive decisions
- No.
- Yes, I like to know whether a product I've purchased may have impacted negatively on the environment, in its production.

9. Provide some guidelines that you think designers should follow when they create industrially-produced products with sustainability in mind.

- Hanover principles, etc.
- Durability – how long will it last; embodied energy – how much energy will it take to make the product; recyclability/reusability.
- Raw materials should be extracted without (much?) environmental harm; design must be such that components are recyclable – easily dismantled and sent to scrap industry; reduction of energy cost for consumer use; use of product must not harm environment.
- I think explanations of operation, strengths, weaknesses, costs all need to be explained.
- price; use of materials that will last and have little repairs required; are universally accepted and approved by various regulatory boards
- function over form as form tends to be esoteric and short-lived
- Try not to fuse unlike materials together to allow for greater recyclability; try to have manufacturing occur near location of materials
- production impact on environment; source of raw materials; lifespan of product; impact of disposal – recycle or landfill; social impact on community where industry is situated
- must incorporate recyclability at the end of their life; must consider packaging and embodied energy and toxic materials, local labour
- make products so that they aren't obsolete models in a year or two – make products so that if a new advancement is created later on for that product, it can be enhanced or adapted (Computers are examples of where this is done poorly.)

10. Have you heard of take-back policies? Examples?

- Yes, Interface carpet.
- Retail stores generally have take-back policies.
- I know of no examples, but I understand this to refer to manufacturers' willingness to take back products after use in order to recycle for new products.
- Yes. Electronic components I often purchase detail take-back.
- No – 7 responses
- yes, carpet example I gave earlier
- if you are not 100% satisfied with a product, you should be able to return it for a full refund
- yes, Philips' policy that it will take back products and re-use all the component parts of that old product. A fantastic idea.

11. **Do you think products should have built-in guarantees and servicing?**

- Yes – 11 responses
- These would be good selling points but I can't see legislation being introduced to compel this.
- Yes, proper design should be backed up with manufacturer's guarantee.
- Guarantees of length of service under X conditions; I believe service agreements add too much to the price of products.
- some
- most definitely. Many products aren't made well to begin with and sometimes the servicing of a product is more expensive than just going out and buying a new one

12. **Are you concerned with the environmental damage of industry and production relative to material goods? Explain.**

- Yes – 2 responses
- Yes. Often the environmental cost of manufacturing a product is not taken into account.
- Yes. We all want the material goods, but the price we pay does not normally include environmental damage caused in the chain of manufacturing processes.
- Yes, but information to public on this issue is not good.
- Yes. Packaging of goods goes to landfills. Consumerism promotes waste as an acceptable social norm and people fill their garages with stuff that ends up ultimately going to the landfill.
- Yes, companies should be environmentally aware of the by-products they produce when creating goods
- Yes, random short-sighted use of economic, public resources (water, air, etc.) is not good.
- I am very concerned with the Western world's use of cheap labour and poorer environmental standards to manufacture goods in Third World areas
- Yes, often the environmental impact of producing a product far outweighs its value in terms of effort to deal with the waste and byproducts
- Yes, water and air pollution are no secret. Today in Edmonton, a car left outside, unmoved, requires washing every three days because of the air pollution that settles on it overnight. That was not the case ten years ago.
- yes, environmental damage is tantamount to rape!
- yes, I'm concerned with the toxicity of materials used in products, as well as any toxic side products, and their disposal, involved in the production

Part two - Design and knowledge about solar products

1. **Describe any other experience you have that relates to solar collectors.**
 - solar workshop
 - solar hot tub; built solar hot water collectors; installed collectors
 - I have a solar shingle on my roof. I have experimented with solar cookers in winter. As well, I have a flat-plate collector on my deck. I also have a solar-powered flashlight and battery charger.
 - Have taken part in three or four workshops. Have had two collector arrays on roof.
 - Fifth WHL installed – one panel.
 - junior high school project to build a series of solar devices but nothing since then (and that was some time ago).
 - None – 3 responses
 - only with solar panel on RV for charging batteries
 - solar water heater on father-in-law's pool (homemade)
 - just from reading some articles and taking solar energy course (Metro College)
 - flashlight; calculator
 - I have measured their performance, helped install them, gazed at them, helped build them, helped to take them down
 - I've read some information about their efficiency and usefulness in providing energy
2. **Do you presently have any solar products in your possession? Describe.**
 - solar calculator – 5 responses
 - solar calculator – often, was not enough light for it to run effectively
 - solar hot water collectors (4); photovoltaic panels
 - solar powered flashlight, battery charger, flat-plate collector, rain barrel, solar shingle.
 - 20-tube array for solar DHW; solar cooker
 - one unregulated .5 Amp panel for fifth WHL
 - No – 3 responses
 - yes, PV, windows
3. **Describe any flat plate solar panels that can be purchased on the market now and provide general information about where it may be purchased.**
 - B.P., Shell
 - The only manufactured product in Canada is Thermodynamics. They are in Nova Scotia. Flat-plate collectors can be purchased in the United States and Europe via the Internet.
 - Would have to research this.
 - Solex. .5 AMP unregulated solar panel – Canadian Tire.
 - know little about products at this point
 - a big question! I haven't bought any
4. **Notate any websites, publications, or books that you think are particularly relevant to the design and manufacture of solar water heating panels.**
 - *Home Power Magazine*; www.solarenergysociety.ca; www.ecn.ab.ca/sesci
 - Would have to research this.
 - Just starting to explore
5. **If you were to purchase a solar system would you wish to use it domestically or commercially? Explain use.**
 - Domestically and commercially. Domestic for personal use if costs can be reduced. Commercially for provincial parks building.
 - domestically – 4 responses
 - Domestically to heat my hot water for showers.
 - Domestically – preheater for DHW tank.
 - Domestically for home water heating and perhaps for household heating.

- domestically. I'd use it to heat water, home space, provide electricity, if I had a place that would accommodate it
- domestically for cabin and RV
- domestically for hot water
- domestically for hot water, likely supplementing the gas water heater
- domestically – I am renovating a kitchen and bathroom and wish to use solar panels for this area only
- domestic – for electricity, heating, water
- both, on my house and sell to businesses

6. **Which application(s) would you most likely need or want for your present situation?**

- potable water – 9 responses
- cleaning and bathing water – 14 responses
- radiant heating system - 7 responses
- greenhouse -
- swimming pool -
- other – electricity-generation

7. **If you purchased a solar panel, would you retrofit it to an existing structure or incorporate into a new design?**

- Retrofit an existing structure – 7 responses
- Both
- I would try to retrofit it to any existing structure.
- new design for cabin
- incorporate into a new design. My current house is an energy pig and I want to build a more energy efficient home.
- Both – considering moving and selling present home.
- retrofit to a 50-year old house
- the panels for the kitchen and bathroom would be a combination of new design and retrofit
- new design
- depends on the place and the cost. I'd try to fit it to an existing structure first.

8. **What is the highest amount you would be prepared to pay for a solar water-heating panel?**

- \$350 – 2 responses
- \$500 – 5 responses
- \$600 – 3 responses one respondent said: depending on size
another said: I believe in most cases, you get what you pay for
- other – 3 responses

Comments:

- Depends on the system. Panel can be the lowest price of the whole system.
- would have to examine the return on investment.
- need to do some research before answering
- no idea until I research the options more
- if it's more expensive than \$600, but pulls down my energy costs dramatically, I'd consider the higher cost end

9. **What is the highest amount you would be prepared to pay for installation of a solar water heating system? A system would include two panels and hookup.**

\$1400 – 2 responses

\$1700 – 4 responses

\$2000 – 2 responses

other – 6 responses – one person said: \$2500

Other comments:

- Depends on payback/reliability
- It depends on how much I would save as a result of implementing the technology.
- would have to examine the return on investment
- need to do some research before answering
- no idea until I research the options more, but I think if the system including installation was more than \$2000 to \$3000, I would hesitate.
- again, this would depend on the possible energy savings. I'd invest in it more money if I could see the long-term cost savings that would result.

10. **Health and safety considerations for solar collector include fire, burns, flooding, damage to home structures, and fumes. Do you have any specific concerns about these or others? Explain.**

- Flooding.
- No – 5 responses
- Fire danger can be almost eliminated by avoiding combustibles in collector construction and allowing air to circulate round collector. Burns need not occur. Hot pipes should be insulated. Flooding will not happen if in a drainback system there is an unbroken fall in the return flow. I had a freeze-break at a point where the level rose briefly on the drain-back decline. Fumes?
- Yes, but safety can be addressed in proper design of structure.
- No, as long as I get approval from various inspectors/agencies.
- no, they should be covered by the homeowner's insurance.
- excess hot water on high solar days
- no, because they need to meet national standards for their safety
- I'd want to know about all the possible risks. However, I'd hope the product would be made well enough and if installed properly, that it would withstand such risks quite well.

11. **Are you aware of any environmental damage that solar panels may cause? Explain.**

- Depends on manufacturing process used.
- Once they are made and installed, I am not aware of any environmental damage they may cause.
- Only at some stages of the manufacturing process.
- No, not enough information on materials is known by myself.
- Only thing I can think of is if it's a glycol system, and it springs a leak.
- No – 8 responses
- the amount of space they take? wild animal impact?
- using energy to manufacture them, causing waste in their manufacture

12. **Are you aware of any specific environmental damage caused by the production of: glass, aluminum, copper, fiberglass insulation?**

- Yes, climate change from intensive energy use.
- Yes.
- I know aluminum is very energy intensive. I suspect the other products are as well. Fiberglass insulation is a health concern.
- I am aware of environmental problems in these areas but I do not know enough to quantify them.

- mining byproducts, smelting, ground and air pollution.
- No – 8 responses
- these (glass, aluminum, copper, fiberglass) require heat to product (thermal impact)

Part three – Instructional design and assembly

1. Would you consider building a house?

Yes – 13 responses

No – 3 responses

2. Would you remodel your own kitchen?

Yes – 11 responses

No – 5 responses

3. Do you hire a plumber to fix your leaky toilet and/or taps?

Yes – 5 responses

No – 11 responses

4. Do you consider yourself:

- construction expert – 1 response
- a specialist with a trade or tickets – mechanic
- handy-person – 10 responses
- novice – 5 responses
- other – designer with knowledge

5. Have you purchased self-assembly kits in the past? Provide up to three examples.

- IKEA – at least three; garage door opener, tub surround
- furniture; beds; bookcases; jig-saw puzzles
- bookcases from IKEA; woodshed
- car alarm; transistors; diodes; ONT CKT. board then wiring to car; garage package; command start for car
- closet door kits, furnace kit, fireplace kit, toilet kits, IKEA furniture, computer, air tool systems, room fans, bike kits, electrical fixtures – the list keeps going, there's a lot of stuff.
- No.
- storage sheds, closet organizers, desks
- Lego mostly
- IKEA furniture – 2 responses
- are you referring to solar panels? If so, no. garage from Totem; other products, such as IKEA furniture and products from Revy, Home Depot – yes
- blinds; furniture; lamps
- central vacuum system; soft water system; garage package (with overhead door assembly)
- bookshelf

6. Is there any company that presently manufactures self-assembly kits that you think does a good job?

- IKEA – 4 responses
- Fairmount Tamper, installing highrail onto trucks to run on railroad tracks
- I don't know, I can't say I've ever purchased multiple units from any one company.
- Lego
- don't know
- IKEA isn't bad, but some of their visual instruction sheets are lousy

7. **Are there any companies that you feel have produced poor kits?**
- Too many
 - I once bought a kit for a picnic table in which some of the cedar 2'x4's were not usable. Have forgotten the company.
 - home-all garage package – very general instructions
 - most computer assembly instructions suck
 - don't know
 - No
 - can't name any specifically
8. **What irritates you the most with instructions that come with products (VCRs, tables, washing machines etc.) Provide detailed examples if possible.**
- not enough pictures – too many options, incompatible with existing situation.
 - not detailed enough – i.e., specifications.
 - not being able to understand the directions, or visualize the 2-D drawing in 3-D.
 - Including too many models in one set of instructions; following instructions faithfully and then at some point finding that nothing happens or something unpredictable happens.
 - poor set-up – jumps from one end to the other; no final result statement; should have overview as to what should be expected out of product.
 - I like lots of pictures that detail the parts and where they go. Detailed instructions take a lot of time to read and to digest – I prefer lots of descriptive diagrams.
 - too long, too wordy and redundant.
 - too many language crammed onto a few pages and not enough pictures
 - if the instructions pertain to a slightly different model; translated English isn't always very clear which doesn't bother me *if* there is a picture alongside
 - trying to find the English version
 - one booklet usually covers every model the company makes – wading through verbiage is tedious – one ends up using common sense
 - not enough visuals
 - not enough visual illustrations
 - poor translation from another language – obvious that whoever developed the instructions did not try to use them themselves
 - they have vague instructions (sparse descriptions), poorly labelled and drawn pictures. I think they attempt to create “simple” instructions but in the end leave out too much. Or else there's so much writing and not enough emphasis on good visual layout, white space
9. **Would you have a preference for instructions that are: (You can mark more than one if they apply.)**
- written out instructions – 12 responses
visual instructions – 12 responses
multimedia (video) – 7 responses
- Other comments:
- Combination of written out instructions and visual instructions. If very complicated, a CD-ROM.
 - I think it is easiest to learn by watching someone else do it.
 - written out instructions with pictures
 - if these are done correctly (the written out instructions and visual instructions), there is no need for video
 - IKEA ones are usually fine
 - both (written out and visual instructions), in case I understand more of one than the other
10. **Would you want information included in a brochure that discusses the effect that the manufacture of a product would have on the environment?**
- Yes – 7 responses
 - I think that it would be an interesting concept. To learn all the processes and mining etc.

required to produce the product.

- Yes. These issues need elaboration, but I would keep this part of the instructions very short.

- Yes, more of this should be known of all products.

- Yes, good promotion.

- yes, can't imagine this happening

- absolutely

- sure

- yes, we don't realize or appreciate much of where the component materials come from, how they're made. More awareness of where these things come from is beneficial

**11. Is time an issue when it comes to assembling a product that you have purchased?
Elaborate.**

Yes – 6 responses

No – 7 responses

Comments:

- Everyone is busy. At least more than a full day is too long.

- I think you would want something that could be put together fairly quickly and easily.

- Of course, no one wants to waste time on anything but as long as one can proceed doggedly from one step to the next, there's no problem.

- I do not mind spending the time if end result is worth it.

- If time is an issue, I usually hire someone to do the work.

- Too long, equals complicated

- more time equals more labour-intensive

- if it's complicated, it must take more time

- not really, unless it will take days and days – that should be stated on the package

- not the first time – it is after all a learning experience. Knowledge gained here can be transferred to other situations

- time is somewhat of an issue. Complexity and tools and skills needed is more of an issue

- if something requires "self-assembly", I would expect to be able to do it efficiently within a relatively short period of time (a week/2 weeks? for large projects and less time for smaller projects)

12. Would you purchase all necessary tools for the assembly?

- I really have most everything already.

- unknown, what tools are required.

- If they were all common tools, I would probably purchase them.

- I would assume I had the necessary tools already. I would consider buying if I lacked a tool. Depends on cost and general usability of the tool.

- Yes, I should have most of the tools already.

- Depends on the tools. If they are one-time use and specific only to this installation, I would not want to buy them.

- No – prefer to use main tools that I have already.

- Yes – 3 responses

- within reason

- depends... it may/would be cheaper to hire someone to install it

- that depends – screwdrivers are one thing – a post auger is another. Rental is advisable in many situations (and it is a green thing to do).

- if necessary

- if it's a tool I would use again in the future, then yes – if not, I would rent one.

- not necessarily

13. Would you consider renting tools if they were specified?

Yes – 16 responses

No –

Why or why not?

- Rather rent expensive tools than buy
- For specialty tools suited only for one application, then I would rent them.
- If the tool is rather special.
- Adding onto my own home I rented many tools that made no sense to purchase.
- If I have no need for the tool after the project is completed, I won't buy it.
- If not too costly.
- cost-effective
- cheaper to rent especially if it's used only once
- cost of tool vs. cost of rental in context of future applications
- so I wouldn't have the expense of their purchase
- it would save on costs and I might never use the tool ever again afterwards!

14. Would you likely get assistance from a spouse, family member, neighbour, in assembling something or do you like the challenge of constructing on your own?

- Like to do it myself.
- Yes – 4 responses
- I usually like working with someone else.
- I prefer working with one or two others. Doubt that one person could handle a DHW collector alone.
- Working in a group promotes good discussions.
- friend or neighbour
- on my own
- definitely I would get help
- family member
- I never turn down help
- I like the challenge but if I'm in over my head, I will ask a friend or family for help
- either
- yes, particularly one friend who is incredibly adept at building cabins, sewing, and building ergonomic devices! I'd also consider family members who are able to assist

15. Have you ever been involved in assembling a solar panel?

Yes – 3 responses

No – 12 responses

Other comments:

- Yes, one workshop.
- Three or four workshops
- workshop in 2000 at HETH

16. If you could purchase an affordable solar water-heating panel, would you want to assemble it yourself or buy it assembled?

- Depends on cost and difficulty of assembly.
- either or
- If it was easy to assemble, I would probably want to tackle it myself.
- Probably would prefer to assemble it myself/ourselves. Presumably there is a difference in price.
- depends on cost savings
- I would need to know more about what is involved before I could answer this.
- Possibly both depending on price and time involved.
- don't know at this time
- assemble it myself – 3 responses
- depends on complexity and effort for assembly
- if self-assembly saves money (a significant amount, that is)
- do it myself. I think it is important to see and understand how things work

- either
 - assembled
17. **Would you self-install or hire a plumber?**
- Plumber – 6 responses
 - Self-install – 6 responses
 - It would depend on how easy it was to reach the hot water tank. If it was hard, I would hire a plumber.
 - Don't know
 - hire spouse
18. **Would you self-assemble a panel if it took less than:**
- 5 hours – 6 responses
 - 7-10 hours – 4 responses
 - 10-14 hours -
 - 14-18 hours – 3 responses
 - Other (2 responses) – 5 hours or 7-10 hours
 - Another respondent said: How ever long it took since mine would be a retrofit application
 - I would do it if less than 5 hours
19. **Indicate size preference for a self-assembly solar panel:**
- 4' x 8' – 3 responses
 - 4' x 6' – 5 responses
 - 2' x 4' – 5 responses
- Comments made in relation to this:
- manageable on a roof by one or two people
 - 2'6" x 6' (sliding door size) There is a range of size less than 4'x8' and more than 2'x4' that would be handleable.
 - 4'x6' or 2'x4' – either something that is too heavy to easily maneuver should be smaller
- Other comments:
- The 2' x 4' panel is probably more manageable.
 - Depends on how large is needed for my job.
 - I don't understand the significance of this question. I would want a panel size that suited the needs of the system being installed. If that could be accomplished with a small panel, then that is what I would install.
 - depends on energy output
 - 4'x8' sheet of plywood size is not easy to maneuver. However, this size could reduce cost of manufacturing and installing right? But it is a two-guy job. The small ones are a one-guy job.
 - don't know

Making a User-friendly Solar Water Heating Panel

Megan Strickfaden - Department of Art and Design - Industrial Design

(Summary of four responses)

HETH Survey Results

Part one - Design and knowledge about solar products

1. **Describe any other experience you have that relates to solar collectors.**
 - little
 - I lived in a house that had a hot water solar system in place. It dated back twenty years and worked well for that time period.
 - None
2. **Do you presently have any solar products in your possession? Describe.**

No – 2 responses

 - flashlights, calculator
3. **Describe any flat plate solar panels that can be purchased on the market now and provide general information about where it may be purchased.**
 - no idea
 - You may want to look at : 30 Below Group in Calgary: Bay A10, 6120 2 St. S.E. Calgary, AB, T2H-2L8 Phone: 287-7888 or Fax:287-7833 or www.30belowgroup.com
 - They specialize in solar powered gateposts.
 - my information is secondhand
4. **Notate any websites, publications, or books that you think are particularly relevant to the design and manufacture of solar water heating panels.**
 - New Concepts of Nano-Crystalline Organic Photovoltaic Devices
 - CADDET Renewable Energy – Internation Demonstration Projects:
<http://www.caddet-re.org/>
5. **If you were to purchase a solar system would you wish to use it domestically or commercially? Explain use.**
 - Domestic. Heat, water, air, and hopefully to power basic things.
 - Domestically. Cut down on energy bills, to be more pro-active in the ecological sense.
 - Domestically. Self-sufficiency and cost-effective within city is my only goal.
6. **Which application(s) would you most likely need or want for your present situation?**

potable water - 1 response
cleaning and bathing water - 4 responses
radiant heating system - 2 responses
greenhouse - 2 responses
swimming pool - 0
other - 0
7. **If you purchased a solar panel, would you retrofit it to an existing structure or incorporate into a new design?**
 - Depends on what kind of a house I own
 - I would retrofit it. But if one could incorporate it into a new design; such as solar shingles or gatepost etc.
 - existing structure with exception being a greenhouse that I would possibly attach to my home
 - retrofit

8. **What is the highest amount you would be prepared to pay for a solar water heating panel?**

\$350

\$500 - 1 response - Assuming that I don't need more than a couple, and maintenance does not cost much.

\$600 - 1 response

other - 0

Comments:

Obviously, the least amount the better. But one may want to devise an alternative system. Why not lease the systems for a monthly fee, or have a payment plan system in place. The biggest downfall so far with this technology is that you are asking people to more less pay for 10 to 20 years of power savings up front. Most Canadian families are not in a situation to do so.

9. **What is the highest amount you would be prepared to pay for installation of a solar water heating system? A system would include two panels and hookup.**

\$1400 - 0

\$1700 - 0

\$2000 - 0

other - 2 responses

Comments:

- All the price above seems much higher than I would like. I am not prepared to spend more than \$1500 total for the panels and installation all together.

- \$500

- It all depends on how quickly it can pay itself off. What savings is one going to see.

10. **Health and safety considerations for solar collector include fire, burns, flooding, damage to home structures, and fumes. Do you have any specific concerns about these or others? Explain.**

No – 2 responses

Durability, safety especially. There can be a lot of pressure running through these systems.

11. **Are you aware of any environmental damage that solar panels may cause? Explain.**

No – 2 responses

No. If you are please let me know.

Yes, damage from mining and manufacturing of parts.

12. **Are you aware of any specific environmental damage caused by the production of: glass, aluminum, copper, fiberglass insulation?**

No – 2 responses

Yes – 1 response (see above).

- I do not know enough on how it is processed, I am sure like any industry there are always concerns. But one should look at the big picture. How much of a reduction in coal consumption, or natural gas use, drilling, tearing up the land, cutting down our forest can be curbed by having solar systems on our businesses, homes, etc.

Part two - HETH workshop

1. **What was your main reason for attending this workshop?**
 - To learn how to make and install a solar panel by myself.
 - To see if it was feasible to run a system like that. To meet people in the industry. Reduce fossil fuel use.
2. **Describe what you gained from participating in this workshop.**
 - Very little. It was much too disorganized and wasteful for me to learn anything.
 - How to build a solar power hot water system. Knowledge and contacts, team work.
 - Knowledge and a working solar panel.
3. **Would you describe the panel construction at the workshop as:**
 - easy - 0
 - medium - 2 responses
 - difficult - 1 response
 - other - 2 responses – one person said “chaos” and the other said, ”chaotic”.
4. **What was the easiest part of the panel construction?**
 - There was nothing difficult about the actual construction.
 - I did not find it difficult to construct the system. Tang’s design was pretty straight forward.
 - It was all about the same.
5. **What was the most difficult part of the panel construction?**
 - Mess. There was no planning in the workshop, and people kept driving back to the hardware stores over and over for little parts. I found it very environmentally unfriendly to waste so much material, gas, and time.
 - Soldering.
 - It was all about the same.
6. **Describe any improvements to the panels you may have thought of after participating in the construction of them.**
 - I think panel itself is O.K. Maybe smaller so it would be easier to install. And hopefully you don't have to spray paint them. How environmentally positive is that?
 - If one can design them lighter. I found them to be very heavy.
 - Too complex and heavy to become popular.
7. **Would you like to participate in a workshop where you could take a completed solar collector home?**
 - Yes if the workshop is well organized and educational. No if it would be like the last one.
 - I would. Living in Calgary makes it a little more difficult for me.
 - If it took two days.
 - Yes and did.

Part three - Instructional design and assembly

1. **Would you consider building a house?** Yes – 1 response, No – 3 responses
2. **Would you remodel your own kitchen?** Yes – 1 response, No – 3 responses
3. **Do you hire a plumber to fix your leaky toilet and/or taps?**
Yes – 1 response, No – 3 responses

4. **Do you consider yourself:**
construction expert - 0
a specialist with a trade or tickets - 0
handy-person – 2 responses
novice – 1 response
5. **Have you purchased self-assembly kits in the past? Provide up to three examples.**
- Just several IKEA furniture.
- Auto parts, shelving units, desks.
- Yes, IKEA furniture.
6. **Is there any company that presently manufactures self-assembly kits that you think does a good job?**
- Sorry, I can't remember who it is but I did get a brochure once about all the solar panel parts.
- IKEA - 2 responses
7. **Are there any companies that you feel have produced poor kits?**
- I haven't seen enough to know which one is good and which one is poor.
- Cannot think of any offhand.
- Yes, but don't remember who.
8. **What irritates you the most with instructions that come with products (VCRs, tables, washing machines etc.) Provide detailed examples if possible.**
- Nothing as long as it is well done. Lack of figures can be a little difficult.
- Diagrams that overlay each other and I suppose terms that many people do not understand.
- Instructions often assume knowledge and often come with incomplete instructions for a novice and faulty pictures.
- Not clear what parts are referred to.
9. **Would you have a preference for instructions that are: (You can mark more than one if they apply.)**
written out instructions - 3 responses
visual instructions - 4 responses
multimedia (video) – 0
10. **Would you want information included in a brochure that discusses the effect that the manufacture of a product would have on the environment?**
- Definitely
- Yes – 2 responses
- I research on my own as brochure allegations are just that and not necessarily true so it is immaterial to me.
11. **Is time an issue when it comes to assembling a product that you have purchased? Elaborate.**
Yes – 3 responses
No – 1 response
- I noticed it took months for the solar panels to go up and function at the Human Ecology House. I couldn't afford that much time. It has to be doable in one weekend.
- It would be an issue before I purchased the product.
- If it isn't cost effective to my time, I would prefer to have it completed professionally.

12. Would you purchase all necessary tools for the assembly?

- If I could afford it, maybe. But most likely not.
- Yes.
- Depending on cost of tools.
- Depends on cost.

13. Would you consider renting tools if they were specified?

Yes – 3 responses

No – 1 response

Why or why not?

- Agree it is a matter of cost and whether or not I would use these tools again.

14. Would you likely get assistance from a spouse, family member, neighbour, in assembling something or do you like the challenge of constructing on your own?

- I would like to do it myself but it would be fun to ask my family to help me as well.
- Sure, as long as they have some type of knowledge on how to assemble something more technically challenging.
- Assistance is a prerequisite, not an option, for any large construction without a complete shop.
- Yes, spouse or family member.

15. If you could purchase an affordable solar water heating panel, would you want to assemble it yourself or buy it assembled?

- Buy it assembled.
- I would prefer assembled. It would greatly depend on price. If there substantial savings for one to assemble the system themselves, then I would do it. But one should include instructions on laws, regulations, codes, that one should be familiar with in order to install a system like that.
- I would buy it assembled, if affordable and efficient.
- Assemble it.

16. Would you self-install or hire a plumber?

- I don't trust my plumbing skills since such a thing does not exist.
- I think the laws would require to hire a plumber to probably connect the final stages of the system.
- self-install
- hire a neighbour

17. Would you self-assemble a panel if it took less than:

5 hours – 1 response

7-10 hours – 2 responses

10-14 hours - 0

14-18 hours - 0

Other - 15 hours

18. Indicate size preference for a self-assembly solar panel:

4' x 8' – 1 response

4' x 6' – 2 responses

2' x 4' – 1 response

other - or smaller

Appendix 7: Component Comparison

Glazing Comparison Solar Collector

The prices in this cost analysis are up-to-date as of December 5, 2000 and they are based on costs from local distributors.

Product	Continuous temperature limits	Drawbacks and Benefits	Cost
New tempered glass Crystal Glass 1/4" x 4' x 8'	230-260°C	• heavy • brittle with possible cracking and breakage	\$298
Used tempered glass Architectural Clearinghouse Various large sizes and thicknesses	230-260°C	• heavy • brittle with possible cracking and breakage	\$50
GE Lexan Polycarbonate sheet Pittsfield, MA 6 mm x 4' x 8'	120-130°C	• light-weight • 10-yr. guarantee for UV-protection • problems with physical and chemical polymers • potential of thermal stress • deformation of plastic • discoloration • embrittlement	\$189
Verolite-Lexan Thermoclear Polycarbonate multiwall sheet Canada 6 mm x 4' x 8'	100-110°C	• light-weight • UV-protected • coating is susceptible to damage • problems with physical and chemical polymers • potential of thermal stress • deformation of plastic • discoloration • embrittlement	\$70

Plumbing Comparison Solar Collector (3'8" x 6'7")

The prices in this cost analysis are estimates for one solar collector. The cost breakdowns are based on wholesale costs of plumbing components from Bartle & Gibson Co., February 6, 2001, and labour costs from Ed Bushy, July 23, 2001.

Option 1 Lee collector	Option 2 Friction fix	Option 3 Plastics	Option 4 Serpentine	Option 5 Copper manifolds
1. copper pipe, M hard 1/2" x 24 \$12.56 x 2	1. copper pipe, M hard 1/2" x 24 \$12.56 x 2	1. PEX* pipe 1/2" x 20' \$6.62	1. copper pipe, K soft 1/2" O.D. x 25 \$18.10 x 2	1. copper pipe, M hard 1/2" x 24' \$12.56 x 2
2. copper tees, 1/2" \$0.54 x 12	2. compression tees, 5/8" \$10.40 x 12	2. copper pipe M hard 1/2" \$12.56 x 2		2. copper pipe, M hard 1" x 8' \$16.53
3. copper elbows, 1/2" \$0.38 x 2	3. compression elbows, 5/8" \$6.89 x 2	3. PEX insert tee, brass 1/2" \$1.13 x 12		3. copper caps 1/2" \$0.90 x 2
4. flux \$1.75		4. PEX insert elbow, copper 1/2" \$0.89 x 2		4. flux \$1.75
5. solder \$3.68		5. PEX insert crimp ring \$0.13 x 46		4. solder \$3.68
6. propane 400g \$3.49 x 2		*PEX is rated for 100 lbs. of pressure and up to 180° F		5. propane \$3.49
Labour 2 hrs @ \$60/hr = \$120	Labour n/a	Labour 1.5 hrs @ \$60/hr = \$90	Labour 1.5 hrs @ \$60/hr = \$90 or CNC \$25	Labour 1.0 hrs @ \$60/hr. = \$60 or manufactured copper manifolds \$125.00/pair
Totals				
\$164.77	\$163.68	\$143.06	\$126.20 manually or \$61.20 CNC	\$112.41 manually or \$187.30 manufactured

Insulation Comparison Solar Collector

The prices in this cost analysis are up-to-date as of July 1, 2001 and they are based on costs from the manufacturers.

Product	Continuous temperature rating	Drawbacks and Benefits	Cost
Durablanket/Kaawool 2' x 5' x 1" roll	2300°F/1260°C	• moisture saturation • bulk ceramic fibres • not resistant to freezing • inorganic • high chemical content	\$8/ft ²
Radiant Barrier 1/2 mil metalized Mylar +1/2 mil aluminum foil 50" x 250' roll Ayr reflective Quebec	240°F/116°C	• humidity resistant • corrosion or delamination resistant • composite material	\$50/roll
Radiant Barrier with recycled fibre-glass 4' x 4' x 1" Ayr reflective Quebec	240°F/116°C	• humidity resistant • corrosion or delamination resistant • composite material • recycled content	\$33/unit
Sprayfoam Insulation polyurethane intermediate 12 oz./340 g can	220°F/104°C	• aerosol can • high chemical content (polymetric hydrocarbon gas, diisocyanate polyols)	\$5.95/can
Reflectix/Ayrfoil Bubbled reflective 1/4" x 48" x 10" Woodbridge, Ontario	200°F/93°C	• low heat resistance • waterproof, vapour barrier • blocks 97% of radiant heat • composite material	\$48.98/roll
Fibre-glass foil face U.S.A. 1" x 48"	200°F/93°C	• moisture saturation • disintegration of paper back on foil • composite material	\$2.98/linear foot
Weathershield/Wallbar Can-cell Industries Edmonton 100% recycled paper	190°F/88°C	• loose-fill material or solidifies when blown-in • requires air space for R-value • recycled material • borate for fire resistance	
Flexotherm/Flexofoil Foil-faced plastic Ontario 48" x 50'	180°F/82°C	• low heat resistance • waterproof, vapour barrier • blocks 97% of radiant heat • composite material	\$49.00/roll
CodeBoard Polystyrene plastic board Celfortec Ohio 1" x 24" x 96"	165°F/74°C	• low heat resistance • will melt	\$8.98/sheet

Rubber and Sealant Comparison Solar Collector

Product	Temperature range	Drawbacks and Benefits
Silicone 300 mL tube	–60°C to 316°C –60°F to 600°F	• versatile • chemically inert
Sponge Rubber — EPDM 1/4" x 3/4" x 10'	–40°C to 50°C –40°F to 100°F	• closed-cell • self-adhesive • composite material • recommended for indoor use
Natural rubber 1/16" — 1/8" Norwesco	–65°C to 120°C –65°F to 250°F	• all-purpose rubber • poor oxidation and ozone resistance • high deformation capacity
Synthetic oil-resistant rubber Nitrile - acrylonitrile butadiene 1/16" — 1/8" Norwesco	–65°C to 150°C –65°F to 300°F	• inferior resistance to ozone, sunlight, natural aging • good resistance to heat
Synthetic oil-resistant rubber Neoprene — polychloroprene 1/16" — 1/8" Norwesco	–40°C to 135°C –40°F to 275°F	• excellent aging qualities • excellent weather resistance, ozone and natural aging
Rubber Black — EPDM hard glazing profile Kawneer part #12-1310 All glass parts	–40°C to 100°C –40°F to 212°F	• good property retention when exposed to heat/cold • excellent weather resistance • excellent recovery from deformation

Paint Solar Collector

Necessary Properties

The coating requires the following characteristics:

- high elasticity due to expansion and contraction with high temperature fluctuations
- heat resistance of at least 212°F
- high resistance to corrosion (i.e., high humidity)
- applied in a very thin layer
- ability to absorb the whole spectrum of light and emit weakly in infrared (i.e., increase solar absorption and decrease long-wave emission)

Selective coatings absorb whole spectrum of sun but emit weakly in infrared.

- specially engineered products
- current research is being done in Russia
- no known available products in North America

Stove or high heat flat black paint can be applied with

- spray gun
- aerosol can

Pump Comparison System Connection

Solar Collector

Pumping System	Size	Head	Max. H₂O temp.	Cost	Total Cost
AC circulating pump Different thermostat	1.7 gpm	30' head	93°C/200°F	\$150.00 120.00	\$270.00
DC circulating pump pv panel Uni-Solar US5	1.7 gpm 5 watt module	30' head	240°F	195.00 US 310.00 69.00 110.00	\$420.00
DC circulating pump pv panel Solarex SX-10 or solar shingle Uni-Solar shingle	3.0 gpm 10 watt 17watt	40-50' head	240°F	219.00 US 340.00	\$560.00

US/Canadian exchange rates based on Nov 3/2001
\$1 US = \$1.59 Canadian

Serpentine Correspondence

Date: Sun, 04 Mar 2001 08:51:04 -0700
From: Dan Langford <dan@planet.eon.net>
To: mstrick@ecn.ab.ca
Subject: Collector design

Hi Megan,

Some quick numbers on the collector designs.

Assuming a 4'x6' collector with a total 2 square meter absorber area and maximum solar energy collected at 800 watts/sq meter.

Flow rate: 3 gal/min. 0.22 l/s (Flow rate of circulation pumps I am using)

- Temperature rise of water in collector: 1.7°C
- Pressure drop in serpentine collector approx. 22,000 Pa or 3.2 psi
- Pressure drop in header collector approx. 19,000 Pa or 2.8 psi

Flow rate: 1 gal/min. 0.074 l/s

- Temperature rise of water in collector: 5.1°C
- Pressure drop in serpentine collector approx. 4500 Pa or 0.6 psi
- Pressure drop in header collector approx. the same as the serpentine collector

Other Assumptions:

No other losses in the collector.

Curves of the serpentine collector are smooth curves with a diameter equal to the width of the absorber plates.

Absorber area of each collector is the same.

Considerations:

Serpentine collector cannot be used in drainback.

Serpentine collector may be difficult to purge air out of.

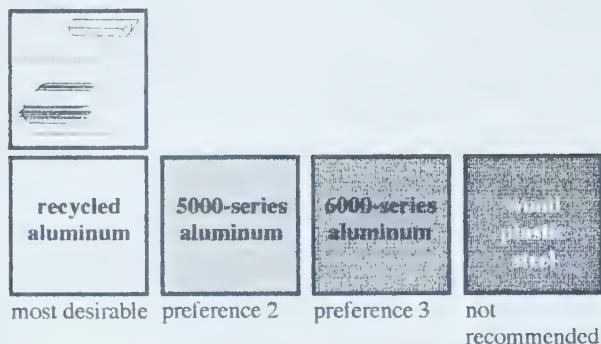
No considerable difference in collector efficiency or temperature differences between designs.

Hope this answers some of the questions brought out at the meeting.

Dan

Appendix 8: Material selection

Frame



A variety of possible materials for the frame were explored before coming to the conclusion that aluminum was the material of choice. Wood and steel have been used in solar collector designs for hundreds of years, but these are not necessarily the best choices today. Wood is prone to warping, twisting, shrinking, swelling and cracking and is not durable under the weather conditions in the province of Alberta. Wood is also susceptible to insect damage and fungal growth. In this climate, wood would be high maintenance since it would require regular preservation treatments. Despite the fact that wood is considered a renewable resource, sustainably grown hardwoods are not readily available in Canada. As a result, durable hardwoods would need to be transported long distances, adding to the expense environmentally. Furthermore, the processes for creating a refined and easily manufactured highly detailed wood frame are not feasible as an industrially-produced product. These technologies have existed for creating house window frames but in the past decade, this process has begun to be illuminated due to the development of vinyl PVC and aluminum frames. Despite the fact that the flat-plate solar collector closely resembles a window frame design, the thermal requirements are quite different. A window frame is set into an insulated wall and it does not encourage heat build-up between the panes of glass. In arid conditions, such as in Israel, steel is a common choice for the frame.

Steel performs much like aluminum but it is heavier and must be treated to prevent corrosion, in order to be durable in this climate. A coating treatment on steel is critical as corrosion reduces the life of a product considerably. Coatings for steel are costly from an

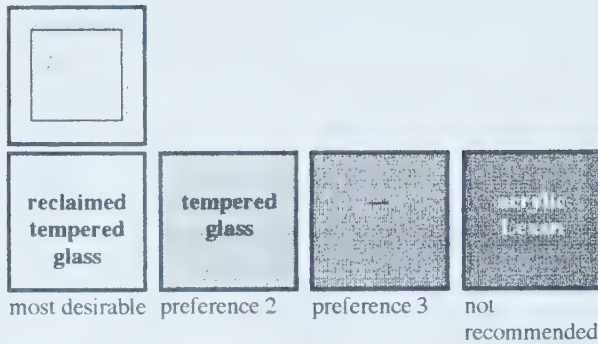
environmental standpoint. Steel has been increasing in price over the past five years due to availability of depleting resources. Recycled steel, on the other hand, requires 39% of the energy used to produce virgin steel, which makes it an appealing option.¹

Ultimately, aluminum was chosen due to its predictability and a wide temperature range, making it resilient to thermal expansion and contraction. Aluminum is also non-combustible and does not emit any toxins when exposed to high temperatures. It has a high strength-to-weight ratio and has good formability. Natural oxide coatings form on the surface of aluminum when exposed to air, which seals the metal. There is no need to paint an aluminum frame. Aluminum is combined with traces of other alloys for durability and formability. All combinations of aluminum are highly recyclable. Aluminum is the most abundant of metals, also most durable with potential for high-grade re-use. The extraction and production processes used to create aluminum are harmful to the environment. In mining and extracting any metal, the amount of usable raw material depends on the richness of the ores extracted. Landscape and nature can be seriously damaged due to changes in groundwater levels and emissions of harmful substances. The raw material bauxite is mined then converted into a semi-manufactured product. In this conversion process, it demands a great deal of energy, typically electricity. In this way, the environmental damage is done in the production.

Recycled aluminum can include between 2—90% virgin material. It is most common to use 45% virgin material and 55% recycled.² Aluminum recycling and reuse can take many forms. At present, the majority of aluminum recycled is pop cans, which are made into new pop cans. Aluminum recycling for extrusion is not occurring in Canada at this time. It is known to be possible, however with the majority of extrusions designed for architecture in this province, a 6000-series structural aluminum is deemed necessary. The market works on supply and demand, which is emphasized by a representative from the *Recycling Council of Alberta*, who stated that Alberta could be ready for other applications of recycled aluminum.

Stainless steel is used for the screws that hold the frame together. It is corrosion resistant created by adding chromium during steel production. Stainless steel is an iron-based alloy that is 10.5% chromium, nickel, manganese, molybdenum, sulfur, selenium, and titanium. New technologies allow stainless steel to be recycled, when necessary.

Glazing



Acrylic is an engineered thermoplastic, polymethyl methacrylate (PMMA), which has some of the necessary properties such as outstanding weatherability, good dimensional stability, and 92% transmittance. Some material flaws are discoloration and cracking when exposed to high temperatures. It also scratches easily under ordinary circumstances. Poor weatherability and heat shortens the life of acrylic since the ability for the material to collect the whole spectrum of light is disabled. As well, acrylic can be readily ignited and creates excessive smoke and off-gassing in conditions of fire.³

Lexan (PC) another engineered thermoplastic is more costly than acrylic and performs better under the required thermal conditions. If glazing were being used without the need for any weatherstripping or rubber, Lexan would be a good product. Unfortunately, PCs are not compatible with EPDM rubber⁴, which is the recommended material for the glazing bead. It may not potentially perform for as many consecutive years as tempered glass, but is protected from vandalism as it is impact-resistant.

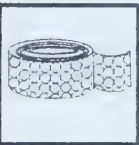
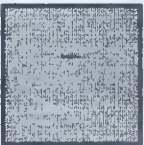
The recommended material for the solar collector glazing is tempered glass. Regular glass is not appropriate as it breaks more readily and can be very dangerous in its broken form. Both regular glass and tempered glass is adequate for solar transmittance and has good resistance to weathering. Glass is composed of silica, lime and sodium carbonate. To produce a sheet of glass, molten glass is drawn through a series of rollers, where it solidifies and is cut to size. After the glass is rolled, both sides have rough surfaces and therefore need grinding and polishing. Standard roller bed width is just over 8 feet, which is why standard sheets come in a 4' x 8' dimension. Large amounts of energy are used to produce glass. Thermal tempering is a process where heat is added to the glass

surface, then is quickly chilled to improve the strength of the glass. Tempered glass requires a great deal of energy in the manufacture process.

Regular glass can be recycled by re-melting, but tempered glass cannot be recycled. In the recycle process, even a new sheet glass can tolerate very little contamination by recycled glass. As a rule, glass waste can only be recycled into low-grade glass. Tempered glass cannot be cut after it is tempered, so it is difficult to re-use unless the required dimensions are readily available. Reclaimed sheet glass is desirable but realistically would not be easy to get in the correct size and thickness. Additional negative characteristics relative to tempered glass are that it has a low impact resistance therefore shatters more easily than plastic products.

There has been some research done on glazing and glazing films that improve the performance of both glass and thermoplastics—these are called selective surface coatings. Unfortunately, many of the films created for solar applications, degrade by becoming scratched and peel off in normal outdoor conditions. As well, these selective surface coatings are not readily available. It is necessary for material engineers to develop an overall material that is more appropriate for the thermal requirements and the conditions necessary.

Insulation

			
FRFF and PEBS			
most desirable	preference 2	preference 3	not recommended

There are a variety of different insulation products available on the market. After researching all the families of insulation—glass, mineral-fiber, cellulose, rigid foamed plastic, and polyurethane foam—fiberglass is considered to be the most common insulation. The first phase of manufacture for fiberglass is the same as glass, whereby the fibers are drawn or extruded through small holes in a glass furnace. The melting process of glass is what requires much of the energy consumption. Glass fibers cause irritation to

the skin and mucous membranes; therefore, working with fiberglass requires good ventilation and personal protection.

There are many new insulation products being developed and sold, most of which are not appropriate as they are made from composite plastic products and do not have the thermal requirements. The other family of products that will not work for the solar collector is natural products such as mineral-fiber and cellulose, since they are loose fill materials that do not have the needed structural integrity.

The Lee collector commonly incorporated the *Foil-faced* fiber-glass insulation for the backpanel. Three problems with this particular product are: it is a composite made from paper, aluminum foil and fiberglass; it is easily moisture saturated; and it does not have the thermal resistance necessary for the solar product. In addition, the *Foil-faced* material is being discontinued, since there are many new products that exceed its R-value.

Unfortunately, the insulation needed for the frame cannot be the same material as for the backpanel. The most convenient insulation product to use for the frame of the solar collector is a polyurethane (PUR) sprayfoam. Environmentally, it is unacceptable since it comes in an aerosol can and the foaming agent used to create the foam is known to cause ozone damage. It is also high in chemical content, which can cause health hazards. The material recommended for the frame is also manufactured by *Ayr-Reflective* and is a 'bubbled reflective'. It is available in appropriate dimensions, 3/8" x 1" x 10', is waterproof and has the correct thermal requirements. It is, unfortunately, a composite material with two layers of bubbles, aluminum and white vinyl. In comparing all the possible selections and their impact on people an/or the environment, this one was the least harmful.

Pipes



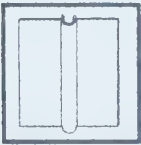
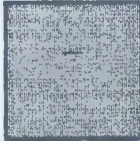
recycled copper	copper	aluminum pipe and absorber	any plastic material
most desirable	preference 2	preference 3	not recommended

There are a variety of materials that are used to make differently dimensioned pipes. There are synthetic pipes made from PVC, PE, and PP, which do not corrode. However, they do not possess the thermal requirements for a solar collection system. Ceramic pipes have a cleaner production process than synthetics and are recyclable or degradable. Ceramic pipes are not available in the needed dimensions and would not receive heat well from the absorber plates. Lead pipes were commonly used in the past but are now known to be hazardous because lead is soluble in water. Legislation in Europe now states that lead cannot be used, even in soldered joints. North America will likely follow suit shortly. Aluminum is subject to corrosion when it is used for a pipe as the liquid slowly degrades the pipe and causes minute pits which later turn to fractures. Aluminum pipes are commonly used, and are a possibility, however the public's perception of aluminum mixed with potable water is negative. Aluminum content in potable water is not desirable due to its connection with kidney disease and Alzheimer's disease. In fact, it is a highly acid liquid that causes a break-down of aluminum making it soluble, and it is likely that the liquid transfer fluid will never reach an acidic state. In addition, the solar collections system connection that is recommended is a closed-loop system meaning that the potable water will never reach the water used in the solar collection pipes.

Compatibility with existing structures is important, and since copper is typically used in domestic and commercial plumbing applications in Canada, it is natural to use this in a solar collection system for ease of hook-up. Copper collects top dollar at the recyclers since there have been declining ores for quite some time. Recycled copper is commonly used in pipe production and copper has the highest recycle rate in the trades above all other materials and metals. New and recycled copper have excellent corrosion

resistance due to a protective coating, verdigris. This naturally-formed protection resists weathering and lengthens the lifespan of copper. In addition, copper has high thermal conductivity and is compatible with aluminum. The availability of copper, in the plumbing industry makes it an appealing material to use. There are several varieties of copper available, a hard and a soft pliable one, all available in the appropriate dimensions.

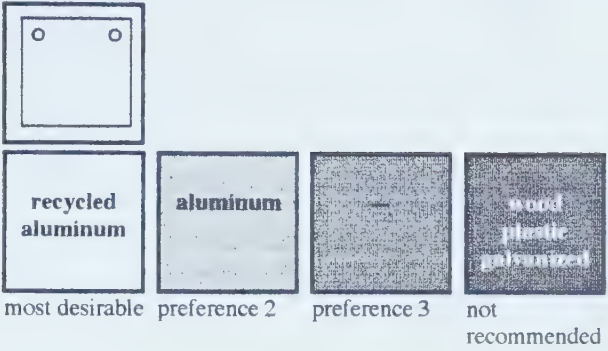
Absorber plates and paint

			
 aluminum			 any plastics product
most desirable	preference 2	preference 3	not recommended
 flat-black high heat stove paint			 acrylic spray paint
most desirable	preference 2	preference 3	not recommended

The absorber plate would be made from aluminum as it is a material that transfers heat well, is less expensive than copper and is easily extruded. In addition, since the frame is already aluminum, it is best to continue with the same material to reduce the need to separate materials at the product-end-life and for ease of recyclability.

The recommended surface coating for the absorber plates is flat-black high heat paint available from a stove finisher or paint manufacturer. It is sold in 1-quart quantities and can be sprayed on the absorber plates for a relatively low cost.

Backpanel

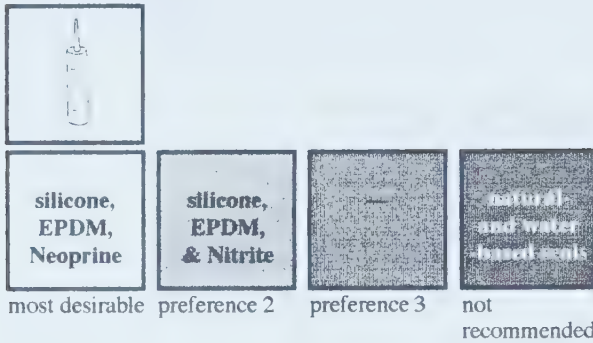


The backpanel can essentially be any flat sheet material that comes in a 4' x 4' dimension. In many home-built solar panels, the backpanel is plywood or a scrap material, since it typically is not visible. The use of materials such as plywood, oriented strand board (OSB) and medium density fiberboard (MDF) are not recommended since they all use toxic bonding agents. Some of the manufacturers of these products are now aware that the use of formaldehyde in such products is becoming undesirable since they off-gas for long periods of time.

A sheet metal is recommended, of which there are two choices: galvanized steel and aluminum. Galvanized steel is essentially a composite material because it is sheet steel that has been electroplated with zinc. Zinc is considered a scarce resource and it has a short lifespan since it is soft and zinc particles mix easily with water. Zinc is harmful to water quality and organisms, being far worse for the environment than people. Galvanized steel can be recycled but the zinc and steel must be separated first, making recycle a time consuming and expensive process. Finally, with the rising cost of steel, galvanized sheet metal is no longer considered an inexpensive metal, as it was in the past.

Sheet aluminum is not as rigid as galvanized steel because it is a softer metal. Aluminum was the most expensive metal but now it is more readily available and therefore less expensive. Sheet aluminum is available in recycled stock and is recyclable. The recycled aluminum sheet is excellent for this application especially since aluminum is already used in both the frame and the absorber plate.

Seals and sealants



The three necessary sealant situations for the flat-plate solar collector are for sealing the miter joints on the frame; for holding the glazing in place and creating a seal between the frame and glazing; and for creating a thermal break between the absorber plate and frame.

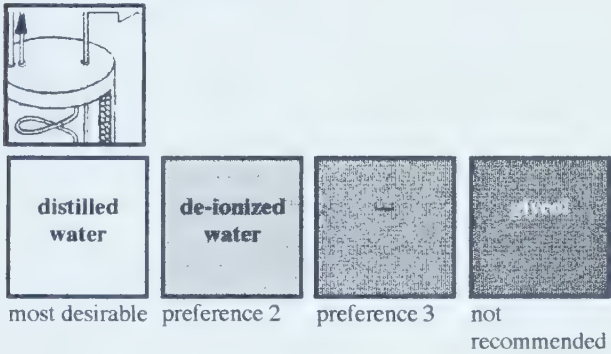
Silicon is an elastomeric sealant that cannot be avoided because of its thermal tolerances. It is recommended to be used for sealing the frame. Silicone can expand and contract and meet all functional demands—air-tightness and weathering. Silicone is long-lasting, 20 to 25 years. There are many water-soluble sealants and natural plastic sealants available made from renewable materials and water. The production of these natural products does not threaten the environment through production processes or toxic out-gassing. However, these environmentally-friendly products do not have the thermal requirements for this project. All sealants, whether water-soluble or not, resemble paint in its composition including bonding agents, fillers, primers, and hardeners. The empty tubes can be recycled, but silicone and other sealants cannot be reused because of their strong adhesion and the generally small amounts that are used.

A soft open-celled EPDM weatherstripping with an adhesive back is used in the Lee collector. The open-cell EPDM does not have an adequate temperature range, but in a harder formulation it has the appropriate thermal properties. EPDM is an elastomer and is hard-wearing, flame retardant, permanently resilient, recyclable and can be extruded, which means there is no waste in the production process from off-cuts. EPDM requires relatively low energy costs for processing. The scrap can be recycled by grinding it down and re-using it as a granulate filler. A UV stabilizer called carbon-black is used in order to make the product more durable. EPDM is not compatible with all glazing options, such as PCs (Lexan) which would

have been one of the recommended material for the glazing had it not been incompatible with EPDM.

For the thermal break, there are two possible materials, Nitrile and Neoprene. Each have the appropriate thermal qualities but Neoprene is superior for aging, weather resistance and ozone resistance. Both Nitrile and Neoprene need to be cut from a sheet material, so there is a certain degree of waste created if the thermal break is curved in any way. The thermal break can be square in shape, therefore waste is eliminated in the production process.

Heat transfer fluids



The two major types of transfer fluids are anti-freeze (glycol) and water. Glycol is commonly used in closed loop systems but can cause corrosion in aluminum, steel, brass, and especially copper and soldered joints. There are two types of glycol: ethylene glycol, and propylene glycol. They have different operating temperatures and propylene glycol is considered ‘virtually’ non-toxic. Just 3 oz. of pure ethylene glycol and approximately 30 oz. of propylene glycol is lethal when ingested.⁵ Glycol requires a high degree of maintenance beginning with mixing the necessary ratio of glycol-to-water. If there is too much water in the mixture, the fluid can freeze, and if there is too much glycol corrosion can occur in the pipes. In addition, the glycol must be tested regularly for pH balance. A glycol solar collection system should be tested every six months and the mixture should be changed every two years.⁶ I would not recommend any type of anti-freeze or glycol mixture for a domestic liquid solar heating system. This is due to the toxic nature of the chemical, and its impact on human health and the environment.

Ultimately, water is the ideal heat transfer fluid because it has a relatively high heat capacity, high thermal conductivity and low viscosity. When passed through copper, it needs to

be a low carbonate, low in chloride, distilled or de-ionized water because it can cause build-up and corrosion in the pipes. Water is easy to attain, easy to dispose of, is non-flammable, and is non-toxic. The only perceived limitation with water is a relatively limited operation range of 40°F to 210°F. In Alberta and Saskatchewan, the most successful solar collector systems use water in a draindown transfer loop.

¹ Spiegel, Ross and Meadows, Dru. 1999.

² Anink, D. et al. 1998.

³ Lorriman, D. 1978.

⁴ Lesko, Jim. 1999.

⁵ Harte, J. et al. 1991.

⁶ Homann, Peter and Hilleary, Chris. 1981.

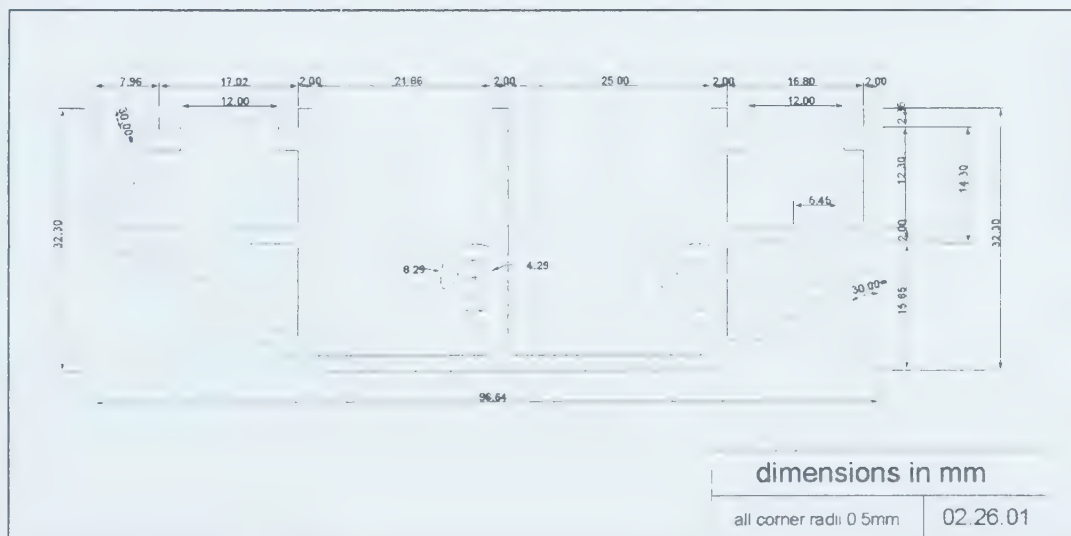
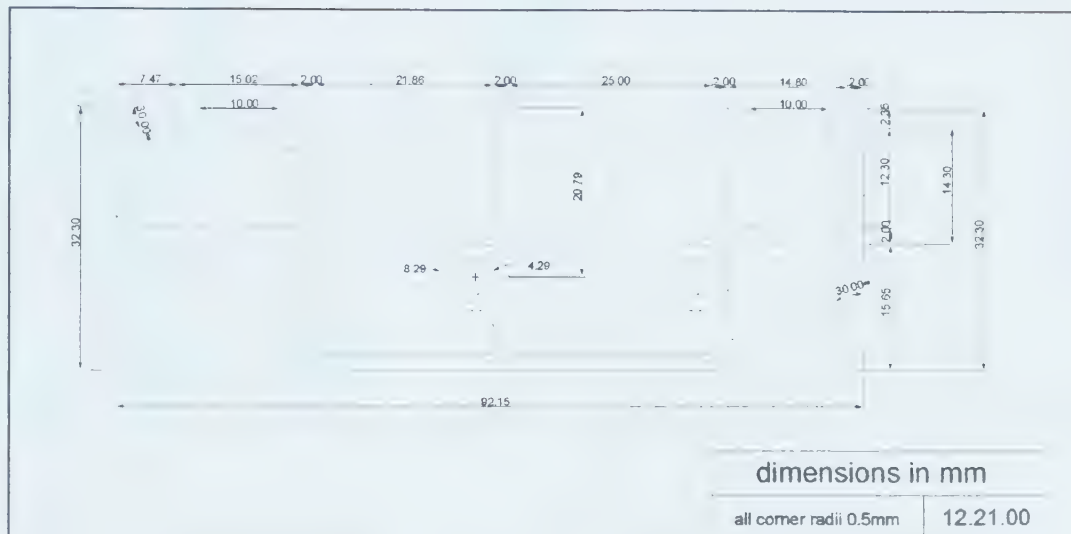
Appendix 9: Number of Components and Materials Comparison

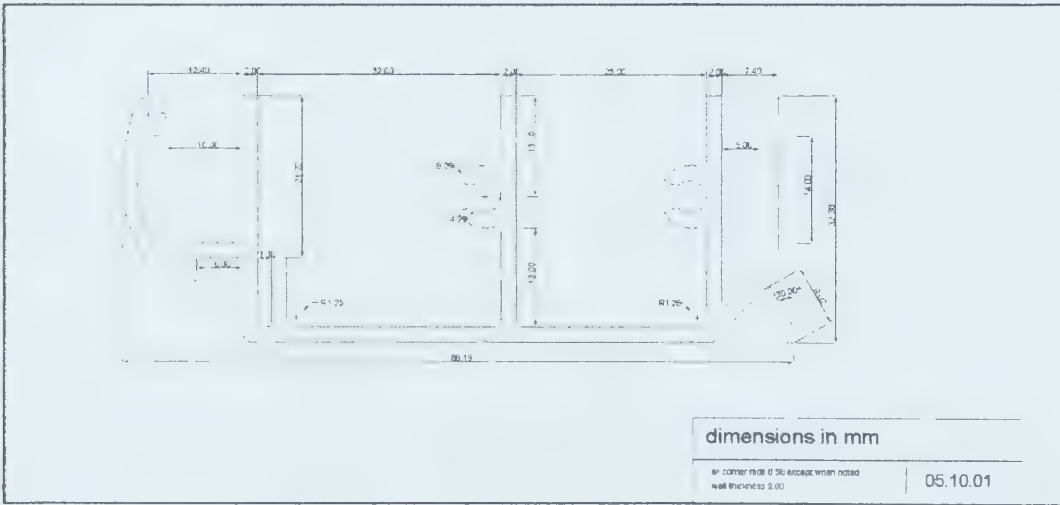
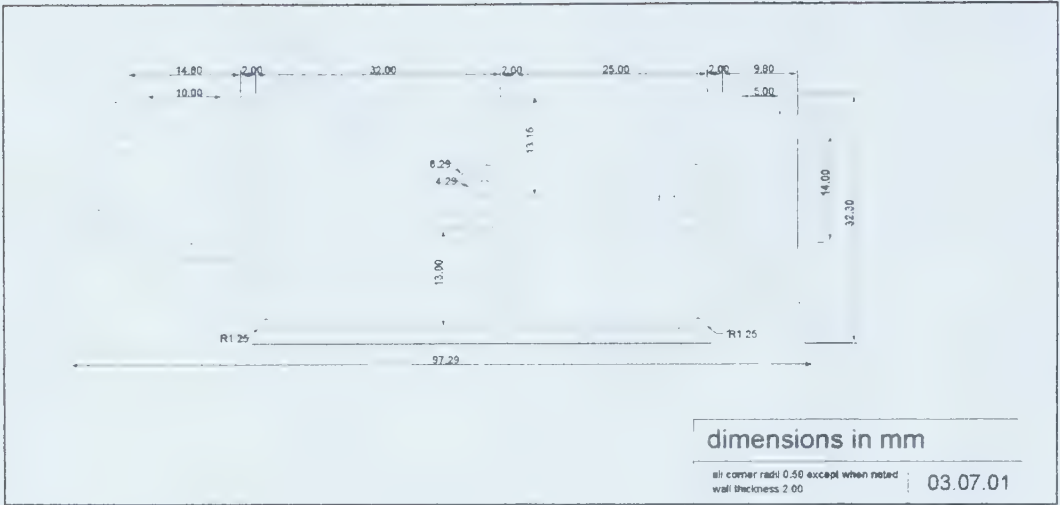
Item #	Component	Material	Lee collector	Final design	
1	glazing	tempered glass	X	tempered glass	X
2	frame	aluminum	X X	aluminum	X
3	backpanel	galvanized steel	X	aluminum	X
4	rivets	aluminum	X	n/a	—
5	bolt	stainless steel	X	n/a	—
6	washer	stainless steel	X	n/a	—
7	screws	stainless steel	X	stainless steel	X
8	pipe	copper	X	copper	X
9	elbows	copper	X	n/a	—
10	tees	copper	X	n/a	—
11	absorber plate	aluminum	X	aluminum	X
12	insulation	paper/foil/ fibreglass	X	foil/fibreglass	X
13	sealant	silicone	X	silicone	X
14	sealant	Neoprene adhesive weatherstripping	X	glazing bead EPDM rubber	X
15	foil tape	foil tape adhesive	X	n/a	—
16	flux	flux	X	n/a	—
17	solder	solder	X	n/a	—
18	propane	propane	X	n/a	—
19	paint	heat-resistant stove paint (aerosol)	X	heat-resistant stove paint (aerosol)	X
20	thermal break	Neoprene	X	Neoprene	X
Total number of Lee components			21	Total number of new components	11
Total number of different materials			17	Total number of different materials	10

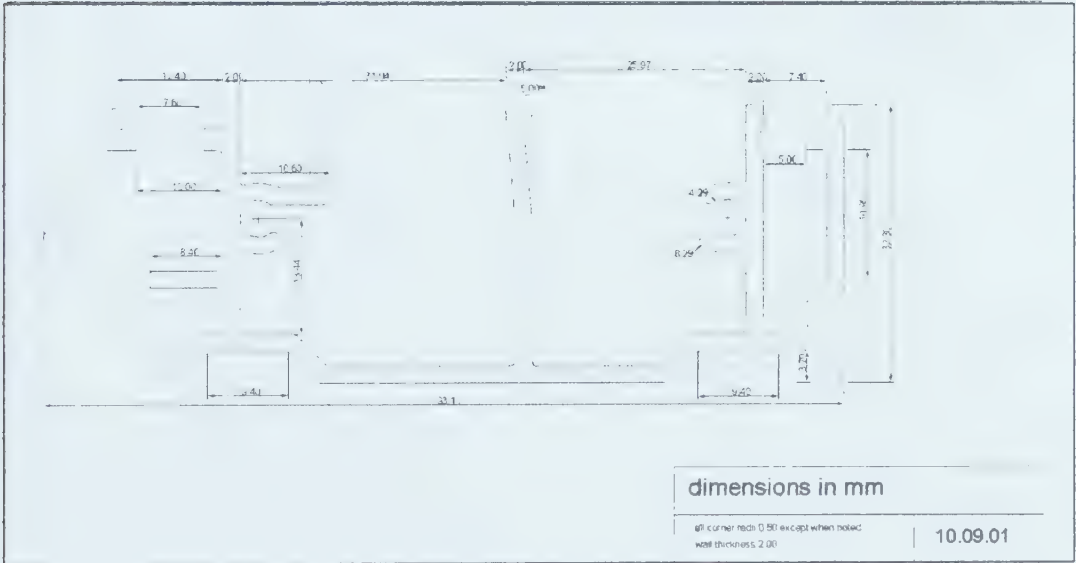
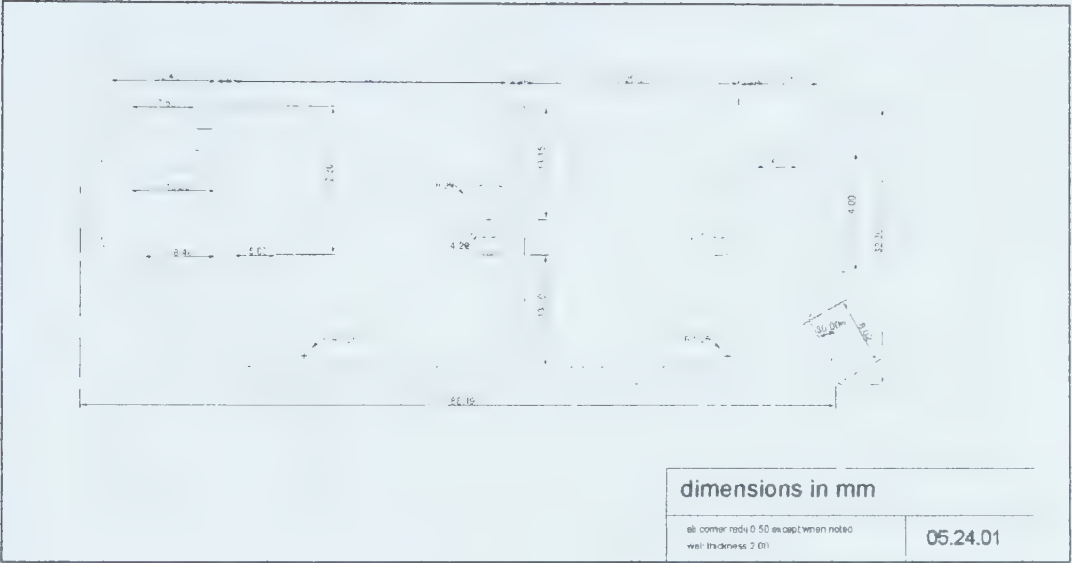
Appendix 10: Tools Needed

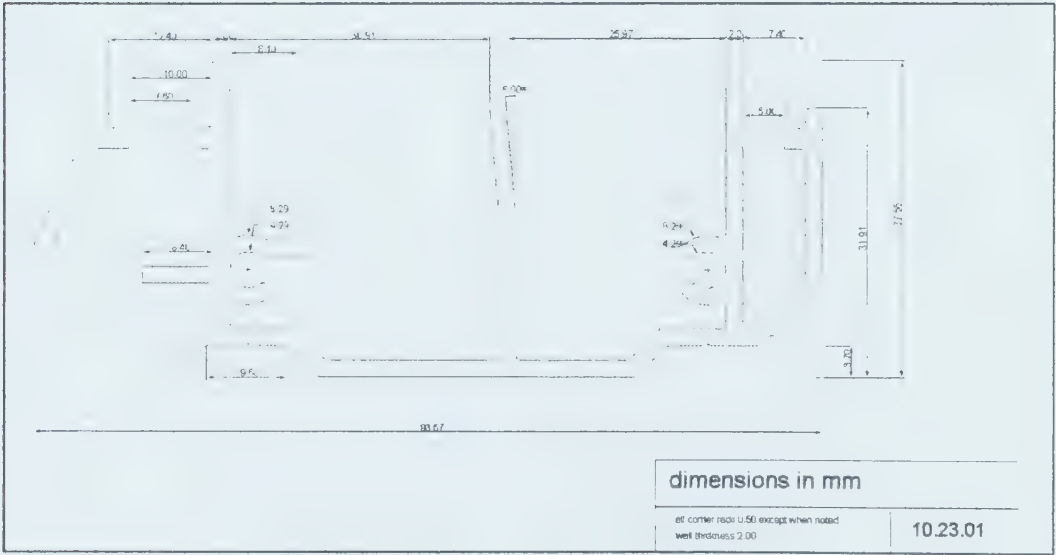
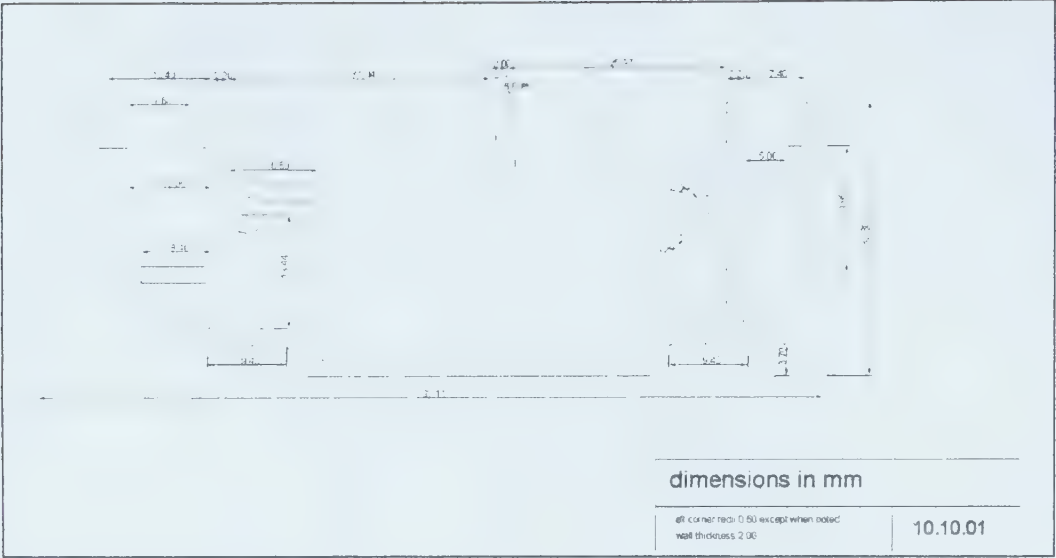
Item #	Tool Description	Use	Lee collector	Single extrusion Cost analysis C	Single extrusion Final design
1	worktables	cutting extrusion, soldering pipes	X	X	X
2	gloves	working with pipes	X	X	X
3	safety glasses	for all purposes	X	X	X
4	vapour mask	for painting	X	X	n/a
5	ladder	to install collector	X	X	X
6	extension cords	for jigsaw, drill	X	X	X
7	jigsaw	cutting extrusion	X	X	n/a
8	drill	drilling guideholes on frame	X	X	X
9	drill bits	same as above	X	X	X
10	hole cutter	cutting hole in frame	X	X	n/a
11	pipe cutter	cutting pipe	X	X	n/a
12	tin snips	cut galvanized steel	X	n/a	n/a
13	center punch	for guideholes on frame	X	n/a	n/a
14	rubber mallet	putting pipes together	X	X	n/a
15	hammer	various uses	X	X	n/a
16	socket wrench	install glass	X	n/a	n/a
17	screwdriver	put frame together	X	X	X
18	scissors	weatherstripping, insulation	X	X	X
19	propane torch or solder gun	solder pipes	X	X	n/a
20	caulking gun	seal the frame	X	X	X
21	rivet gun	backpanel installation	X	n/a	n/a
22	break	to fold galvanized steel - backplate	X	n/a	n/a
23	hose adaptor	test pipes for leakage	X	X	n/a
		Total number of tools	23	18	10

Appendix 11: Extrusion Profiles with Dimensions









Appendix 12: System connection options

Summary of the types of solar collection systems

A solar collection system is comprised of three separate components:

1. **The collector**
2. **The transfer system** which includes plumbing components (piping, expansion joints, valves, pressure relief valve, vacuum relief valve, tempering valve, expansion tank); insulation (for piping, tanks, heat exchangers); electrical (temperature sensors, wiring, circuit breaker); and heat exchangers
3. **The heat storage system** which can be in the form of a specialized storage tank or a conventional water tank

There are several companies that manufacture flat-plate solar collectors, but few companies deal with the entire solar collection system other than providing loose schematic drawings for installation. These installation details do not take into account different climates and maintenance issues.

The weakest point in the solar thermal heating system is the liquid transfer component. In addition, there are a number of other potential issues related to installation of solar collection systems including potential health hazards and a general lack of expertise in the field of solar installation and maintenance.

In general, the simpler the system, the longer it will last with the potential for the owner to take responsibility for maintenance and repairs.

There are a number of observed and documented problems that relate to the transfer of the medium between the collector and the storage components. The two major concerns in solar collection system design is to 1) design-in freeze protection, and 2) allow for thermal expansion and contraction. These and some additional design considerations for developing a low maintenance solar collection system are itemized below.

Pipes and Insulation:

- transfer systems tends to be hidden
- installation requires breaking the structural envelope which becomes vulnerable to ice dams and drainage issues
- components are vulnerable to expansion and contraction which causes movement in the system and potential leakage
- piping is exposed to the weather and is vulnerable to degradation and freezing
- flexible connections need to be inspected and maintained regularly because the materials used are more vulnerable to degradation and corrosion (i.e., rubber hardens and loses elasticity causes slippage and is vulnerable to UV rays, vinyl and nylon lose their properties and become brittle in the cold)
- flexible connection materials need to be chosen carefully to isolate dissimilar metals
- clamps require regular tightening and can compress rubber or plastic materials ultimately destroying seals
- insulation and insulation casing is vulnerable to weather
- adhesions, bonding agents and silicones malfunction in heat and cold
- hangers must be of adequate design and appropriate materials to withstand weather and hold the weight of water-filled pipes

Water flow and storage:

- biological growth can occur in storage tank
- algae can cause particle build up in the pipes
- use of bactericides and fungicides can affect water quality
- stagnation of water can break-down glycol mixtures

Controls, valves and electronics:

- sensors are inadequately protected from weather
- sensors are vulnerable to the high temperatures that are encouraged in solar collectors
- coatings break down on sensors
- sensors need to be positioned in 'flow area' to be effective and are easily placed in an inappropriate location
- access to sensors is inadequate for maintenance
- the user cannot adjust set points once an installation has occurred
- mechanical pneumatic valve and damper valves respond slowly
- solenoid valve close too quickly
- pump size must suit the system requirements
- pumps rely on sensors to act when needed

Hazards relative to people:

- high pressures in the solar collection system
- high temperatures of water, pipes and storage tanks
- contamination of potable water
- damages to structure such as flooding and fire
- toxic out-gassing can occur when materials are in contact with continual heat

Four types of solar collection systems

I. Thermosyphon

The thermosyphon system is sometimes categorized as a passive solar system. It is maintained at a standard household pressure of 50 psi and involves no pumps or electronic controls.

The thermosyphon system works on the principle that heat rises. The sun hits the water that is in the solar collector. When the water is heated it rises and circulation begins. The water flows through the collector outlet and into a holding tank that is mounted above the collectors. Cooler water falls to the bottom of the tank and into the collector creating a natural loop. The water continues to flow as long as it is being heated.

The thermosyphon system is simple but may be most appropriate for new design situations where it is feasible to place storage tanks in an upper story of a structure.

II. Pumped glycol

The pumped glycol system is an indirect system that is maintained in a closed loop. It is necessary to use a heat exchanger with the glycol system which can be single-walled or double-walled.

Typically, propylene glycol is used as the transfer fluid. Propylene glycol is considered to be food-grade safe and non flammable, however, it consists of chemical properties which do have negative health effects in animals and people. When heated the propylene glycol begins to evaporate and attaches itself to airborne dust which can enter the bloodstream. Propylene glycol is not considered to be a carcinogen but can cause headaches and throat irritation. It is particularly problematic for people with respiratory problems. Propylene glycol also contributes to ozone depletion and air pollution. When changing the glycol solution, the old glycol would need to be disposed of safely which requires considerable responsibility for the user.

Typical problems with pumped glycol systems are the possibility of contamination to the potable water, the breakdown of antifreeze resulting in freeze up, corrosion of heat exchangers and maintenance issues. To avoid contamination of potable water, it is recommended that a double-walled heat exchanger be used. When stagnation occurs in the glycol system, the glycolic and oxalic acid attacks

metals. Furthermore glycol breaks down seals and gaskets causing potential leakage elsewhere in the system. The glycol would need to be changed periodically to maintain the pH level and to ensure a proper ratio of glycol to water mixture. If the mixture is too weak it can allow freeze-up and if it is too strong it can cause corrosion. Access to heat exchangers for servicing and maintenance is a potential problem, particularly with a single-walled, internal system. Parts can be difficult to access making maintenance practically impossible. With a double-walled system, there may be considerable heat transfer loss. There are several heat exchange units available on the market, however it is difficult to judge the most efficient and maintenance-free system.

The pumped glycol system requires a higher degree of maintenance on multiple levels but allows for a virtually freeze-free system.

III. Drainback

The drainback system is an indirect system that operates in closed loop. The drainback system can use water or a glycol mixture. With the drainback system, a pump pushes the liquid through the pipes and into a heat transfer device. The pump works in combination with a differential thermostat which keys the pump to work only when the fluid is being heated. When the pump stops, air is admitted to the down-pipe which imbalances the collector loop and causes the fluid to drain back to the storage tank or heat transfer tank. Typically the piping is sloped in the collector and on route to the transfer tank, this allows for ease of drainback. A power failure will cause drainback because the system essentially shuts down. For full freeze protection, CSA standards state that all fluids from exterior pipes must be evacuated in less than 3 minutes.

IV. Draindown

The draindown system is easily confused with the drainback system as the terms have been used interchangeably by many members of the solar community. The main difference between the draindown and the drainback system is that the draindown system is a direct system that uses water and feeds into a secondary storage tank or an existing water tank.

This system involves the use of thermostats and pumps and relies on the evacuation of water from the solar collector and pipes to prevent freezing. Solar failure can occur due to pipe freezing and therefore this system relies more heavily on the insulation of the fluid transfer lines. The maintenance requirements in the draindown system are more visible and ultimately more manageable.

Additional design considerations are the distance of pipe and the electronic devices employed. With PV solar pumps, many of the temperature measuring devices can be eliminated since the pump will be active when the sun is shining.

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Appendix 13: Sustainable features

Designed for resource conservation

- using the minimum amount of material required for the function of the solar collector (i.e., weight reduction — which reduces the cost of manufacture, saves resources and energy, less material that needs to be disposed of at the product's end-of-life)
- using a minimum number of components and assemblies
- using a minimum number of different materials
- using off-the-shelf materials rather than specialty-designed components (i.e., copper plumbing pipe used for better compatibility with existing plumbing systems in houses)

Designed for environmentally-preferred manufacture

- avoiding materials which deplete limited natural resources and does not compromise the efficiency of the solar collector
- avoiding materials made with toxic or hazardous materials (i.e., materials that scientific studies indicate cause serious health effects through contact or through industrial extraction and manufacture processes; for example, lead which is used in solders and paints, and glycol in solar collector systems, could potentially get into the primary water system of a home)
- avoiding ozone-depleting substances (i.e., substances such as CFCs in propellant aerosols)
- using recycled materials (i.e., recycled aluminum, glass fiber¹)
- using recyclable materials (i.e., aluminum, copper)
- avoiding using composite materials which cannot be separated in the recycle process
- avoiding the waste of materials by using dimensions that relate to materials being manufactured thereby reducing cut-off waste of materials
- simplifying assemblies by making a solar collector that is easy to put together and to take apart (i.e., using non-specialized tools that do not destroy the product in disassembly)
- using local manufacturers of parts and materials
- taking into consideration the environmental impact of transporting materials and parts from afar (i.e., recycled aluminum from Alberta)

Designed for efficient distribution

- packaging that includes renewables such as cardboard made from post-consumer waste and hemp fibres, printing with soy-based inks, and using water-soluble adhesives for the labels
- packaging made from one material with no plastics or metal products
- packaging that is multi-purpose (i.e., protects the solar collector during transportation and storage, and also serves to promote and market the solar collector)
- packaging that can be sent back to the manufacturer for reuse for the packaging of another solar panel kit — this is part of the manufacturer take-back policy

¹ Recycled aluminum uses 23% of the energy required by virgin aluminum while glass fiber uses 88% of the energy required by virgin glass. (See Gertsakis, John et al., *Good Design, Better Business, Cleaner World: A Guide to EcoReDesign—Improving the Environmental Performance of Manufactured Products*, Centre for Redesign at RMIT, Australia 1997.)

- instructions that are staple-free, printed using soy-based inks, on paper made from post-consumer waste
- reducing the overall weight of the solar collector for ease of transport and self-assembly
- transporting the solar collector most efficiently by rail for long distances and road for short distances

Product use

- multi-purpose use as an air- or water-heating solar collector
- can act as signage in addition to heat collection
- designed to allow for efficiency improvements (i.e., the frame is designed with high tolerances for change and internal components and glazing can be replaced with more efficient materials in the future)
- designed for a range of conditions (i.e., freezing to boiling temperatures and designed for a multitude of different retrofit or new-design situations)
- analyzed for possible failures or problems (i.e., freezing conditions, stagnation conditions)
- designed to avoid energy waste (i.e., potential heat leaks from specific areas and bridges)
- using user feedback mechanisms, such as meters, that encourage product understanding
- durable product, with a long service life of greater than 20 years
- provisions for easy repair and general maintenance done by the owner (i.e., mechanical fasteners that are made from a highly durable material and easily replaced if worn and comprehensive instruction package to assist in assembly and disassembly)
- by assembling the kit, the owner of the solar collector will gain understanding about thermal solar collection
- product support in the community, offered by a non-profit agency (i.e., support for constructing the kit, consultant and/or plumber contacts, a web-site to discuss the use of the sol aquasphere and aerosphere, or other solar products)

End-of-life options

- designed for durability — potential weak points in the design have been identified (i.e., the potential for soldered joint failure is high, therefore all solders inside the solar collector have been eliminated)
- the solar collector can be disassembled and made into an air heater if it is a water heater or vice versa
- the solar collector is easy to disassemble, by opening, loosening, and separating components by hand (i.e., the snap on absorber plates)
- all materials in the solar collector are safe to dispose of — they do not have any toxic content
- the number of interconnected components are minimized by having complete and continuous parts (i.e., the serpentine plumbing pipe)
- the solar collector can be fully disassembled and all components can be recycled — the only material within the collector that needs to be discarded is the foil that surrounds the insulation and the glazing; the parts of highest value are the aluminum frame, backpanel, and absorber plates; all screws are stainless steel and are not as easily recycled; all other parts are recyclable (i.e., rubber, copper)

-
- packaging materials biodegrade naturally with no dispersion of toxins
 - the solar collector can be returned to the manufacturer for recovery, recycle, or reintegration — this is another part of the manufacturer take-back policy

Colophon

A support document in partial fulfillment of the Master of Design degree, Industrial Design, Department of Art and Design, University of Alberta.
Small publication of Megan Strickfaden.

The design of a solar collector and its implications for sustainable design methodology

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Typeface: Times Roman

Paper: NATURALS Writing - Kraft Wove



80% total recycled fibre
45% post-consumer fibres

Slide Inventory

Fine Arts Building Gallery Exhibition

December 4th to 23rd, 2001

*The design of a solar collector and its implications
for sustainable design methodology*

- Slide 1 — Introduction panel
- Slide 2 — Designers statement panel
- Slide 3 — Acknowledgment panel
- Slide 4 — Overall gallery view I
- Slide 5 — Overall gallery view II
- Slide 6 — Sustainable design panel
- Slide 7 — Cradle-to-cradle panel
- Slide 8 — Design for manufacture panel
- Slide 9 — Product longevity panel
- Slide 10 — Function panel
- Slide 11 — Materials panel
- Slide 12 — Product-people relationship panel
- Slide 13 — The Lee solar panel cross-section
- Slide 14 — Extrusion design evolution – frame
Dec. 21, 2000 to Oct. 23, 2001
- Slide 15 — Third generation design cross-
section

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- Slide 16 — The research and design process including: “A nonlinear look at sustainable design”, designers log book, photo documentation, transcription tapes
- Slide 17 — Books of inspiration including:
- Slide 18 — Overall gallery view III
- Slide 19 — Design features panel including: solar panel, instructions and packaging design
- Slide 20 — Full-scale 4'x4' prototypes:
i) New Mexican cloud image on a serpentine-type collector
ii) Manifold-type collector
- Slide 21 — Final extrusion design with all components
- Slide 22 — Design break-away with all components
- Slide 23 — Bathtub with running water hooked up to a solar panel
- Slide 24 — Toolbox with the tools needed to construct a self-assembly kit including: instruction leaflet, installation leaflet, screws and thermal breaks in envelopes
- Slide 25 — Self-assembly solar panel kit 1:6 scale
- Slide 26 — Overall view IV; of instruction-for-assembly leaflet, packaging design and kit-for-assembly
- Slide 27 — Overall view V; of toolbox, instruction-for-assembly leaflet, packaging design and kit-for-assembly



easily recyclable



optimisation of logistics



optimization of materials



recycled content



energy savings



renewable energy



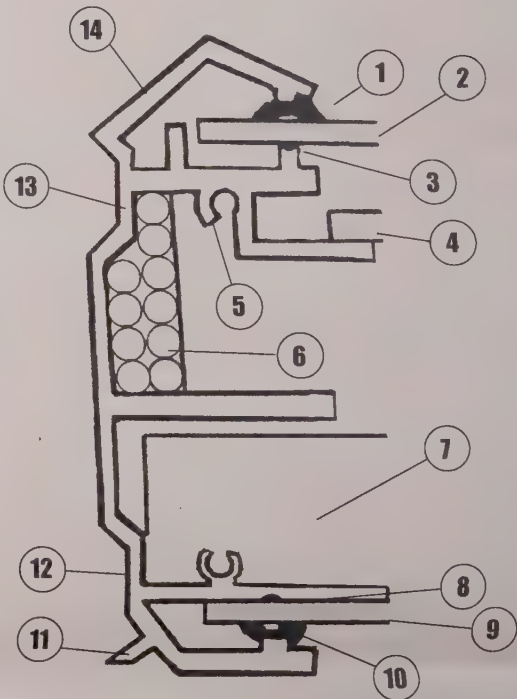
strategy of sustainability



control of the risks linked
with materials and
substances

extrusion detail

1. glazing bead
2. glazing
3. rivet and silicone bead
4. absorber plate
5. weep sleeve
6. frame insulation
7. backpanel/insulation
8. rivet and silicone bead
9. backpanel
10. glazing bead
11. mounting bracket with v-groove
12. frame screw v-groove
13. frame screw v-groove
14. weep hole v-groove



approximate dimensions: 1.5' x 4' x .48" long

the sol aquasphere and sustainability

Cradle-to-cradle sustainable design

For many generations, the use of solar energy has been considered to be supportive of sustainable living. By using the sun as a renewable resource, the thermal solar collector promotes living in balance with the natural environment. This thermal solar collector has been designed with environmental impact in mind as part of the design criteria, which considers the entire product lifespan from cradle-to-cradle.

The sol aquasphere and sol aerosphere solar collectors includes the following sustainable features:

Designed for resource conservation

- using the minimum amount of material required for the function of the solar collector (i.e., weight reduction — which reduces the cost of manufacture, saves resources and energy, less material that needs to be disposed of at the product's end-of-life)
- using a minimum number of components and assemblies
- using a minimum number of different materials
- using off-the-shelf materials rather than specialty-designed components (i.e., copper plumbing pipe used for better compatibility with existing plumbing systems in houses)

Designed for environmentally-preferred manufacture

- avoiding materials which deplete limited natural resources and does not compromise the efficiency of the solar collector
- avoiding materials made with toxic or hazardous materials (i.e., materials that scientific studies indicate cause serious health effects through contact or through industrial extraction and manufacture processes; for example, lead which is used in solders and paints, and glycol in solar collector systems, could potentially get into the primary water system of a home)
- avoiding ozone-depleting substances (i.e., substances such as CFCs in propellant aerosols)
- using recycled materials (i.e., recycled aluminum, glass fiber¹)
- using recyclable materials (i.e., aluminum, copper)
- avoiding using composite materials which cannot be separated in the recycle process
- avoiding the waste of materials by using dimensions that relate to materials being manufactured thereby reducing cut-off waste of materials
- simplifying assemblies by making a solar collector that is easy to put together and to take apart (i.e., using non-specialized tools that do not destroy the product in disassembly)
- using local manufacturers of parts and materials
- taking into consideration the environmental impact of transporting materials and parts from afar (i.e., recycled aluminum from Alberta)

Designed for efficient distribution

- packaging that includes renewables such as cardboard made from post-consumer waste and being fibres, printing with soy-based inks, and using water-soluble adhesives for the labels
- packaging made from one material with no plastics or metal products
- packaging that is multi-purpose (i.e., protects the solar collector during transportation and storage, and also serves to promote and market the solar collector)
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- instructions that are staple-free, printed using soy-based inks, on paper made from post-consumer waste
- reducing the overall weight of the solar collector for ease of transport and self-assembly
- transporting the solar collector most efficiently by rail for long distances and road for short distances

Product use

- multi-purpose use as an air- or water-heating solar collector
- can act as signage in addition to heat collection
- designed to allow for efficiency improvements (i.e., the frame is designed with high tolerances for change and internal components and glazing can be replaced with more efficient materials in the future)
- designed for a range of conditions (i.e., freezing to boiling temperatures and designed for a multitude of different retrofit or new-design situations)
- analyzed for possible failures or problems (i.e., freezing conditions, stagnation conditions)
- designed to avoid energy waste (i.e., potential heat leaks from specific areas and bridges)
- using user feedback mechanisms, such as meters, that encourage product understanding
- durable product, with a long service life of greater than 20 years

- provisions for easy repair and general maintenance done by the owner (i.e., mechanical fasteners that are made from a highly durable material and easily replaced if worn and comprehensive instruction package to assist in assembly and disassembly)
- by assembling the kit, the owner of the solar collector will gain understanding about thermal solar collection
- product support in the community, offered by a non-profit agency (i.e., support for constructing the kit, consultant and/or plumber contacts, a web-site to discuss the use of the sol aquasphere and aerosphere, or other solar products)

End-of-life options

- designed for durability — potential weak points in the design have been identified (i.e., the potential for soldered joint failure is high, therefore all solders inside the solar collector have been eliminated)
- the solar collector can be disassembled and made into an air heater if it is a water heater or vice versa
- the solar collector is easy to disassemble, by opening, loosening, and separating components by hand (i.e., the snap on absorber plates)
- all materials in the solar collector are safe to dispose of — they do not have any toxic content
- the number of interconnected components are minimized by having complete and continuous parts (i.e., the serpentine plumbing pipe)
- the solar collector can be fully disassembled and all components can be recycled — the only material within the collector that needs to be discarded is the foil that surrounds the insulation and the glazing; the parts of highest value are the aluminum frame, backpanel, and absorber plates; all screws are stainless steel and are not as easily recycled; all other parts are recyclable (i.e., rubber, copper)
- packaging materials biodegrade naturally with no dispersion of toxics
- the solar collector can be returned to the manufacturer for recovery, recycle, or reintegration — this is another part of the manufacturer take-back policy

introduction

This solar panel design was originally conceived by architect and professor, Tom Iva, of the University of Calgary. It has undergone a sustainable re-design by Megan Strickland of the University of Alberta. Two kits available, the sol aerosphere and aquasphere, are manufactured by the Solar Energy Society of Canada. Northern Alberta Chapter (SESC-NAC) in Edmonton, Alberta, further information and support for these products can be found at the www.sea.ca/sect web site. SESC-NAC will make every effort to assist you in the construction of your kit, provide consultant or plumber contacts who can help you connect your system to your home and provide community support. SESC-NAC also provides product take-back. If for any reason, at any time, these products are no longer wanted.

Solar collection is not a new technology. It has been around for centuries and has been of particular interest to architects, designers, and the public in times when natural resources have been expensive or unavailable. There are essentially two kinds of solar collectors: passive and active. The most well-known solar collection devices are photovoltaic (PV) systems which are considered active systems because they transform the sun's energy into electricity. The sol aerosphere and aquasphere thermal solar collectors are also considered active systems because there is heat transfer involved. However, these kinds of systems are technologically less advanced and much more cost-effective than PV systems.

Thermal solar collectors use the sun's energy to heat air or water. Their frames are designed to accommodate ducting for air passage or plumbing for water

passage — they cannot do both at once but can be easily modified from one to the other if desired. In both cases, sunlight passes through glazing onto a light-absorbing material known as the absorber plate. The absorber plate collects then transfers the heat to air or water. The solar panel is contained and insulated to prevent the converted sunlight from escaping, maximizing the thermal transfer into heat.

A thermal solar collector does not replace a conventional heating system — it supports it. A back-up system will always be necessary due to daily sunlight fluctuations, seasonal shifts, and varying daily times of heat consumption. It is estimated that, on average, your thermal solar collector will be collecting approximately 70% of the time throughout the year. The sol collectors are designed to work effectively 12 months of the year. It is important to orient the collector(s) vertically on a south-facing exterior wall. This will allow for maximum collection in the coldest months of the year. It is a misconception that solar collector do not work well in colder climates. Detailed investigations have shown that solar collection is, in fact, extremely viable in such circumstances.²

The benefits from having a thermal solar collector can be enormous. Any structure that requires heat can use an air-heating device such as the sol aerosphere. Any thermal solar collecting system reduces the amount of fuel used for heating purposes thereby saving money and conserving natural resources for the community at large. A water solar collection device such as the sol aquasphere is particularly useful for applications such as warming pools, shower rooms, cafeteria settings, and for domestic use.

product features

- easy assembly and installation
- assembly can be done by one or two people
- easily integrated into a building design
- accommodates new installations and retrofitting onto existing buildings
- functional and efficiency performance in colder climates
- all components accommodate thermal expansion and contraction
- product design has provision for a drain-down system
- cost effective product with a three-to-five-year payback
- locally designed and manufactured in Alberta
- product supports sustainable living and sustainable manufacture

cradle-to-cradle sustainable design

For many generations, the use of solar energy has been considered to be supportive of sustainable living. By using the sun as a renewable resource, the thermal solar collector promotes living in balance with the natural environment. This thermal solar collector has been designed with environmental impact in mind as part of the design criteria, which considers the entire product lifespan from cradle-to-cradle.

sol aquasphere



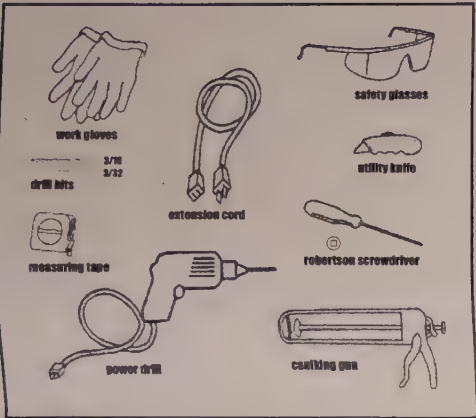
megan strickland

¹ See the Sustainable Lifestyle and Sustainable Manufacturers for sections more details.

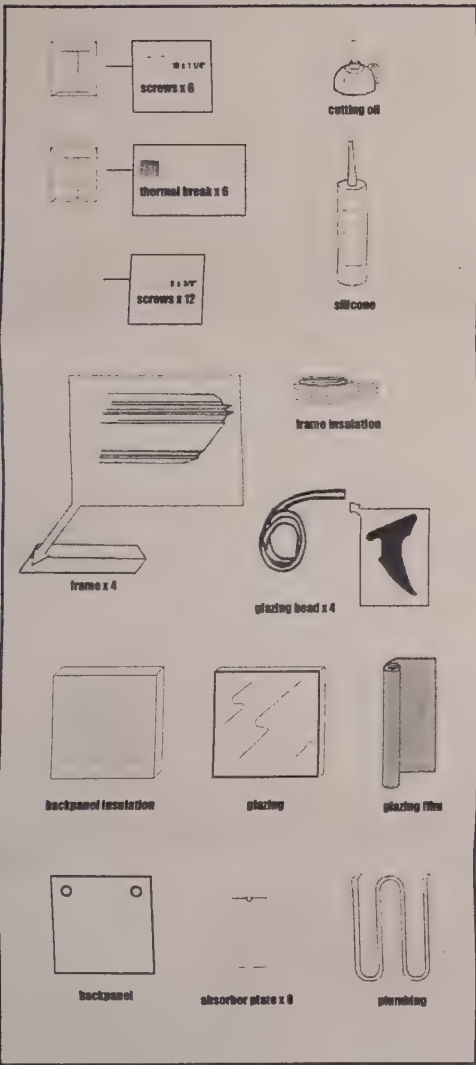
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³ Recycled aluminum uses 22% of the energy required by virgin aluminum while glass fiber uses 84% of the energy required by virgin glass. (See Gottschalk, John et al., David Ruggie, Better Business, Cleaner World & Guide to EcoDesign — Improving the Environmental Performance of Manufactured Products, Centre for EcoDesign at RMIT, Australia 1997.)

tools you will need



materials included in the kit



IMPORTANT: Read entire leaflet before beginning construction!

Approximate kit construction time: 6 to 8 hours

instructions for assembly

1 Measure and mark on two lengths of the frame 1/2" from each end.	2 Drill two holes on each end of the frame with a 3/16" drill bit. Ensure that the drill bit sits in the V-groove.	3 Push two layers of frame insulation into the frame where indicated. You might need to cut these to length (4 ft) with scissors to get the exact length required.	4 Silicone each end of the frame on the mitered corners on one length only.	5 Screw three lengths of frame together by using the screwdriver, larger self-tapping screws, and cutting oil.	6 Allow silicone to dry and set for 1 hour.
7 Run a generous silicone bead along the frame in the indicated divot.	8 Slide aluminum backpanel into place. Ensure it is centered in the frame to allow for thermal expansion and contraction. Do not push against frame edge!	9 Measure and mark on the aluminum backpanel 1/8" from the edge of the frame. Using the 3/32" drill bit, drill three holes at equal intervals on the two frame-facing sides of the backpanel. Use the smaller self-tapping screws to attach the backpanel to the frame.	10 With the back of your solar collector facing up, push rubber glazing head into place. Work towards the corners by starting at the bottom and finishing at the corner. Miter at corners neatly. These are easily removable if you need to re-do them to get them neat. A clean miter at the corners makes a better seal, which will provide the best efficiency.		
11 Allow silicone to dry and set for 30 minutes.	12 (Optional step) If you are using the self-adhesive glazing film, then you must consider the orientation of it before you slide the glazing into the solar collector panel frame. The top of your image must be placed with the two pipe holes running vertically (see step #27). Place the self-adhesive glazing film on the panel according to the enclosed instructions.	13 Snap absorber plates onto the plumbing pipes. If your kit has shorter pieces of absorber plates, fit these together so they are continual.	14 Turn the entire solar collector frame over so you can work on the front. Slide in the foil sheet insulation.	15 Using your utility knife, cut holes in the foil insulation sheet to match holes in the backpanel.	16 Lay in the plumbing with the pipes fitting through to stick out the back.
17 Measure and mark on the absorber plate 1/8" from the frame. Using a 3/32" drill bit, drill three holes at equal intervals on each of the absorber plates overlying the frame. The holes must penetrate the absorber plate and the frame.	18 Place a thermal break band around the edge of the absorber plate at each hole. Use the smaller self-tapping screws to join together the absorber plate, thermal break, and the frame at all six locations.	19 Run a silicone bead along the frame in the indicated divot.	20 Slide the glazing into place. Ensure it is centered in the frame to allow for thermal expansion and contraction. Do not push the glazing tightly against frame edge!	21 With the front of the solar panel facing up, push the rubber glazing head into place on the three sides. Center on panel and miter at corners neatly.	22 Allow silicone to dry and set for 1 hour.
23 Silicone mitered corners of the final length of frame.	24 Screw final length of frame together using larger self-tapping screws and cutting oil.	25 Allow silicone to dry and set for 1 hour.	26 Push the final strips of rubber glazing head into place on both the front and back of the solar collector panel. Silicone the eight mitered corners of the rubber glazing head.	27 Allow silicone to dry and set for 1 hour.	28 Avoid mounting your solar collector for at least 24 hours — the silicone needs to set before installation. For mounting on the wall of a building, always orient the pipes vertically, one above the other, as shown. If this is not done, the water will not drain-down when temperatures are below freezing. This will cause freezing in the pipes, possible breakage, and unnecessary maintenance!

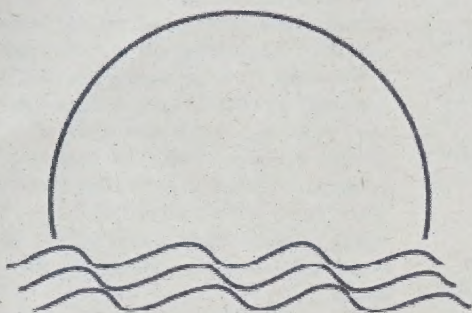
instructions for mounting

Note mounting information in the Important Tips section below

- 1 For mounting, measure and mark the exterior wall of the building with overall panel dimensions and hole placements of your solar collector. Ensure that you place the panel level with the windows and walls. The panel is designed for drain-down, so do not angle the panel, as angling may jeopardize the drain-down system.
- 2 Choose a screw size appropriate to your building, considering the length and size of screw relative to the mounting bracket. Drill two holes on the mounting brackets on three sides of the frame only. In addition, using the 3/16" drill bit, drill 2 more holes at the bottom of your solar collector panel to allow any excess moisture build-up to be able to drain from the panel.
- 3 When mounting more than one panel, panels may be placed flush against one another if desired. For future maintenance purposes, leave one side of each panel accessible. Ensure that there is plenty of room to remove the glazing — a minimum of 4 feet, beside, above, or below the panel.

Important Tips

- Always work in a well-ventilated area, using reasonable safety precautions and safety eyewear.
- Construct the panel indoors in a temperature-controlled and humidity-stable environment where it remains sealed.
- Never skim on silicone. When in doubt, use a lot — this ensures a better seal.
- Never rush silicone drying time as this could affect the efficiency of your solar collector panel(s). Do not mount your solar panel(s) on your building for at least 24 hours to allow the silicone to set completely. This will allow proper air-tight sealing of your solar collector panel(s) and provide the best efficiency possible by minimizing heat loss thus maintaining high temperatures inside the solar collector.
- Use ample amounts of cutting oil to lubricate the screws when you are putting the frame together. This is a self-tapping process and the cutting oil will help to lubricate the screw sleeve thus preventing screw breakage. The frame is made from aluminum which is a soft metal; therefore, when you drive your screws into the aluminum frame, it will leave dust and chips in the screw-tapping process. The excess bits of aluminum may clog the screw sleeve, making it difficult to drive the screws into the frame. Never force the screws because this can cause screw breakage. If a screw breaks, file off the end of the screw to be flush with your frame. Rather than risking a weaker frame, fill in the second hole on that side with silicone. Drill new holes on the opposite face of the miter on that corner of your frame.
- When you place the plumbing, insulation, and glazing into the panel, consider the final mounting of your solar panel. Carefully consider the panel orientation for later maintenance. Note mounting instructions.
- It is recommended that your solar collection panel(s) be mounted on an exterior wall of a building. Always orient the pipes vertically, one above the other as indicated in mounting instructions. If this is not done correctly, the water will not drain-down when temperatures are below freezing. This will cause freezing in the pipes, possible breakage and unnecessary maintenance!
- For mounting your solar collection panel(s), choose a south facing exterior wall high on your building. Site your location for direct sunlight free of shading from landscaping and neighboring houses. Mount solar panels at least 32" below soffits and roof overhangs. If there is an excessive overhang, check for shading at various times of the day over several months. Your solar collection panel(s) should be placed close to a light-colored, highly reflective horizontal surface whenever possible. The light-colored surface may be a cement pad, a balcony floor, or a snow-covered yard. Solar collection will occur all year round but will be more efficient using reflection during the winter months, particularly in colder climates with snow cover. Avoid mounting your panel above dark surfaces such as asphalt or black soil.
- The number of solar panels required will depend on the amount of hot or warm water you consume and the number of people in your home. Typically, 1 panel is sufficient for 1 to 2 people, 2 panels for 2 to 4 people, 3 panels for 4 to 6 people.
- If the solar collector panel needs to be opened, unscrew the four corner screws of that side and use a utility knife to cut the silicone at the mitered joint. Slide that end of the frame off.
- If complete disassembly is required, remove the solar panel from the wall, unscrew one frame edge, remove that end, peel off the rubber glazing bead, slide out glazing, unscrew absorber plates, remove all guts, unscrew backpanel, unscrew and disassemble frame.
- Note that instructions to convert your water heating collector to an air heating collector are available. As well, information about the take-back policy of this solar collector and its recyclability are indicated in this leaflet. Keep this leaflet for future reference.



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A solar collection system is comprised of three separate components:

1. The solar collector panel(s)
2. The transfer system which includes plumbing components (piping, isolation valves); insulation (for interior pipes); electrical (photovoltaic (PV) solar panel power source, wiring); and a direct current (DC) circulating pump
3. The heat storage system is a specialized 300 litre, double-walled, CFC-free insulated (R18+) tank with an internal copper coil heat exchanger

The draindown solar collection system

The draindown system connections is recommended for retrofit and new design situations.

The draindown system is an indirect heat-transfer system that operates in a closed loop. The draindown system can typically use water or a glycol mixture. With this kind of system, a pump pushes the liquid through the pipes and into a heat transfer device.

Typically the pump works in combination with a differential thermostat which prompts the pump to work only when the fluid is being heated. A power failure when using an electrical pump will cause draindown because the system essentially shuts down.

An off-the-grid system connection is recommended for connecting your solar panel to your building. The benefit of an off-the-grid system is that it is self-sufficient and does not require the use of conventional electricity. A PV solar panel provides power for a DC pump. The PV panel also acts as a

controller. When there is more sun it provides more energy to the pump, thus creating more flow through the collector. This eliminates the need for sensors since at peak times of the day, the pump will be in use and at times when there is no sun, such as night time or overcast days, the system can essentially 'sleep' or 'draindown'. The piping is sloped in the aquasphere solar collector and on route to the transfer tank, allowing for ease of draindown. For full freeze protection, CSA standards state that all fluids from exterior pipes must be evacuated in less than 3 minutes. In the case of the aquasphere collector, the collector is completely evacuated within less than 2 minutes.

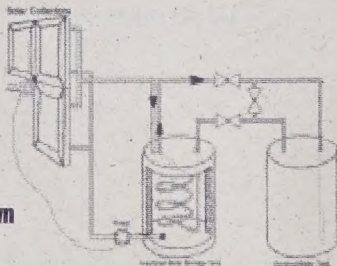
The thermosyphon solar collection system

The thermosyphon system is recommended for new design situations where it is feasible to place storage tanks in an upper story of a structure. Generally, an older home does not have the structural integrity necessary for putting a water storage tank in an attic or loft. The thermosyphon system is less costly and easier to maintain because it does not need electrical components and a circulating pump.

The thermosyphon system is sometimes categorized as a passive solar system. It is maintained at a standard household pressure of 50 psi and involves no pumps or electronic controls.

The thermosyphon system works on the principle that heat rises. The sun hits the water that is in the solar collector. When the water is heated it rises and circulation begins. The water flows through the collector outlet and into a holding tank that is

schematic of the draindown solar collection system

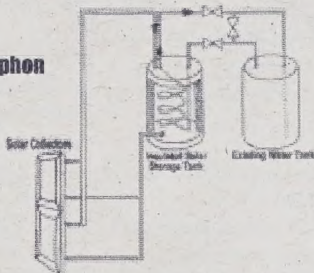


mounted above the collectors. Cooler water falls to the bottom of the tank and into the collector creating a natural flow-through system. The water continues to flow as long as it is being heated.

System connections features

There are a number of observed and documented problems that relate to the transfer of the medium between the collector and the storage components. The two major concerns in solar collection system design are: 1) freeze protection, and 2) allowance for thermal expansion and contraction. The weakest point in a water solar heating system is the liquid transfer component. The simplicity of this system connection makes it easier for the owner to take responsibility for maintenance and repairs. These and some additional design considerations for developing this low maintenance solar collection system are itemized below.

schematic of the thermosyphon solar collection system



Pipes and Insulation

• Installation requires breaking the structural envelope of the building. By doing so, the structure becomes vulnerable to ice dams and drainage issues. The installation of the solar panels on a vertical wall eliminates the need to penetrate the roof, which is the most vulnerable. In penetrating the wall of your building, you should use a drill bit size that is closest to the pipe size coming out of the back of your collector. The holes in your structure should be silicone to eliminate any possible heat leaks. Silicone is the best material for this job since it is inherently flexible and able to withstand the temperature variations (at extreme highs and lows) that will occur within the pipes of the hot water pipe return.

• All the components that connect to your solar collector are vulnerable to expansion and contraction due to extreme temperature variations. This causes movement or shifting of pipes and other components in the system connection and can cause leakage. Any flexible hoses that are used should be placed indoors, as they are vulnerable to weather (UV rays, rain and snow). The solar panel(s) should be mounted as indicated to allow for the panel(s) to stay fixed and stable in relation to the building. This will reduce the thermal movement and prevent connecting pipes and hoses from disconnecting.

• Any piping that is exposed to the weather is vulnerable to degradation and freezing. The sol aquasphere design eliminates the need for any exterior pipes other than those inside the panel itself. In this way, the system is double freeze-protected by using a draindown connection and by keeping all potentially vulnerable pipes indoors.

Water flow and storage

• Within an open system, biological growth can occur in the storage tank and algae can cause particle build-up in the pipes. This is why a closed draindown system is recommended. There is a small reduction of efficiency in the transfer of heat from the copper coil heat exchanger, however, in colder climates the heat transfer system is most reliable and least likely to freeze-up or leak. With a heat exchange system, the solar water never touches the household potable water and water quality is never affected.

• Any type of antifreeze or glycol mixture is not recommended for this system. The pumped glycol system requires a higher degree of maintenance on multiple levels. The draindown system has been in

use for many decades in colder climates. It is a system with the least amount of maintenance. If a glycol system is desired, it is recommended that a double-walled tank and exchanger be used, so there is no possibility of contaminating the system.

Controls, valves, and electronics

• Typical problems in a solar connection system that relate to sensors include:

1) generally being inadequately protected from weather, 2) vulnerable to the high temperatures that are encouraged in solar collectors, 3) sensor coatings breaking down, 4) sensors are often difficult to access for maintenance. In addition, pumps rely on the sensors to act when needed. The sensors have been eliminated from the sol aquasphere collector system to avoid these potential problems. By using a PV panel and DC pump, the sun regulates when the solar collector should be used, thus eliminating the need for a temperature sensor.

• In any solar collection system, the pump size must suit the system requirements. With the sol aquasphere, the 2 USGPM pump has been designed to operate with between 1 and 5 panels at 30 feet of head. This is the optimum distance needed between your storage tank and the solar panels. Other pumps are available if needed.

Hazards relative to people

• Dangers involved with a solar collector include high temperatures of water, pipes and storage tanks. To prevent heat-loss and for safety purposes, pipes that have hot water flowing through them should be insulated. The storage tank is adequately insulated to prevent potential injury. By using your existing water tank, the hot water sensors already in place that sense your hot water will keep water temperatures reasonable and safe.

• Potential damage such as flooding and fire could happen to your building. It is important that regular inspections and maintenance be done by the owner

operating a heating system, whether it is run by natural gas, electricity, or solar. A regular routine by the home-owner should include visible inspections of the collector, transfer system, and storage tank every 6 months. Possible pipeleaks or disconnected wires should be part of this inspection. This will avoid any potential hazards to your building.

• Toxic out-gassing can occur from materials that are in contact with continual heat. The sol aquasphere collector and system have been designed to avoid using any materials that could potentially out-gas. When connecting the solar collection system, it is important to consider the pipes that are used. Choose copper pipes whenever possible and avoid plastic products such as PVC.

• This is for the health and safety of the people occupying the home and for the protection of the environment. Propylene glycol is considered to be food-grade safe and non-flammable. It consists of chemical properties which do have negative health effects in animals or people. When heated, the propylene glycol begins to evaporate and attaches itself to airborne dust which can enter the bloodstream. Propylene glycol is not considered to be a carcinogen but can cause headaches and throat irritation. It is particularly problematic for people with respiratory problems. Propylene glycol also contributes to ozone depletion and air pollution. When stagnation occurs in the glycol system, the glycolic and oxalic acids attack metals. Furthermore, glycol breaks down seals and gaskets causing potential leakage elsewhere in the system. The glycol would need to be changed periodically to maintain the pH level and to ensure a proper ratio of glycol to water mixture. If the mixture is too weak it can allow freeze-up and if it is too strong it can cause corrosion. When changing the glycol solution, the old glycol would need to be disposed of safely which requires considerable responsibility of the user.